Newfoundland and Labrador
Department of Environment
P.O. Box 4750
St. John's, Newfoundland
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COME-BY-CHANCE REFINERY SITE REMEDIATION

November 1987

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ACRES

November 27, 1987
P8143.00

Government of Newfoundland
and Labrador
Department of Environment
P.O. Box 4750
St. John's, Newfoundland
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Attention: Dr. L. Hulett

Dear Dr. Hulett:

Come-by-Chance Refinery
Site Remediation -
Final Report

We take pleasure in submitting 25 copies of our final report on Come-by-Chance Refinery Site Rehabilitation.

This has been a most interesting assignment and we would like to express our appreciation to both your staff and the staff of Environment Canada for their cooperation on this project. It was a pleasure working with them.

We trust we can be of assistance to you again in the future.

Yours very truly,

S Richta

for Maurice S. Mills
Regional Manager

BGB:rs

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EXECUTIVE SUMMARY

This report presents the results of a hydrogeologic investigation designed to examine three previously identified areas of possible contamination in the general vicinity of the Come-by-Chance oil refinery in Newfoundland. The study was commissioned by the Government of Newfoundland and Labrador Department of Environment and was carried out from May to September, 1987 concurrent with the recommissioning of the refinery under new ownership. For each of the three sites, the study examined the extent of contamination in the soil and groundwater and assessed its impact on the environment. Based on these results, a program of remedial cleanup measures has been recommended.

The location of the three sites is shown in Figure 2.1 and these have been designated in the report as the Tank Farm (Site 1), the Mill Building (Site 2) and the Waste Disposal (Site 3) sites. The Tank Farm and Waste Disposal sites are believed to have been used for the disposal of construction waste and some domestic refuse during and following the construction of the refinery (1973 to 1976). All of the waste materials at these two sites were essentially disposed of in an uncontrolled manner with no records available to indicate the type or amount of particular waste material contained in these sites or the disposal practices used. Furthermore, no measures were undertaken to control either the generation of leachate or the migration of contaminants off-site nor to determine whether such measures were necessary. The Mill Building site is not known to have been previously used for the disposal of waste materials but rather was used to store full and empty drums of refinery chemicals. Again, however, records of the chemicals stored and storage practices used are not well documented.

Recommendations

The remedial measures program recommended for the three sites is outlined below.

1. Utilize the Waste Disposal site as a repository for all wastes which are to be secured from the three sites. To secure the Waste Disposal site, a containment scheme involving the placement of a cap and trench cut-off wall around the crown of the site is proposed. Figure 7.2 illustrates details of this scheme in cross-section. The cap will limit the amount of water infiltrating into this area and thus reduce the amount of leachate generated. A collector drain is to be placed around the inside base of the trench cut-off to both reduce the amount of water in contact with the waste materials and to direct the residual leachate generated to a suitable collection point. This drain will also facilitate monitoring of any leachate. It is anticipated that the materials to be used for the cover and cut-off wall can be obtained locally.

2. Prior to implementing the containment scheme for the Waste Disposal site the following action is recommended for the other two sites.

   (a) At the Tank Farm site, the recent disposal of excavated fill and refractory brick over this site effectively masked visual identification of contaminated areas. Therefore, a final decision on any remedial action should be deferred pending some additional testpitting and limited chemical analyses. The outcome of this work will determine whether any material needs to be removed from this site. The only material identified at this time that needs to be removed is from some small oil-stained peat areas adjacent to the site.

(b) At the Mill Building site, 600 m^3 of contaminated soil from the surface layer around the fenced compound and its immediate vicinity should be taken to the Waste Disposal site. In addition, stockpiled drums plus the shallow layer beneath them should be removed to the same location.

3. A program of monitoring groundwater levels and water chemistry should be implemented in order to assess the effectiveness of the remedial works program. This will involve installing a background monitoring well in an area unaffected by refinery activities and continuing to monitor a select number of the wells already completed under this investigation.

The cost of undertaking this remedial measures program, including setting up the monitoring program, is expected to be $400,000 in 1987 dollars. This cost includes an allowance for contingencies, engineering design and supervision, as well as the physical on-site work.

Investigative Program

The field program consisted of augering, testpitting and borehole drilling in order to determine the subsurface conditions at each site. Soil samples were taken from 9 shallow auger borings, 15 testpits, 15 boreholes and a few selected samples of the ground surface for later chemical analyses. In addition to the collection of soil samples, augering and testpitting permitted more detailed visual examination of the soil horizons. Boreholes provided additional information on the soil characteristics and, following the installation of 15 monitoring wells, in-situ hydraulic conductivity. These monitoring wells also facilitated measurement of the position of the water table and the collection of groundwater samples for later chemical analyses.

The chemical analyses which were performed on selected soil and water samples included oil and grease, phenolics and heavy metals. Specific organic compounds were also tested for on individual soil samples. The test results were compared with appropriate soil and water guidelines in order to determine the extent of any contamination. A comparison with background soil and water conditions was also made to assist in this assessment.

The following is a summary of the hydrogeologic conditions and the extent of contamination at each site based on the investigative program.

Tank Farm

This site is located immediately south of the refinery's crude oil storage tanks and occupies an area of about 0.6 ha. The overburden consists of two distinct materials. An older fill of undetermined thickness forms the main body of the site and appears to consist largely of construction waste and domestic refuse mixed with silt, sand and gravel. This in turn is overlain by newer, clean fill which has been excavated from the refinery's new crude pumping station and spread over most of the site.

Although localized areas of low-level soil contamination occur throughout the site, only one area of older fill along the northwest margin was close to removal criteria. This area contained elevated metals and organics suggesting contamination by crude oil, possibly as a result of fire drill activities. The chemical condition of the groundwater was found to be acceptable with little evidence to suggest movement of contaminants off-site.

Mill Building

This 2.5-ha site occupies a flat, low-lying area north of the refinery. This site is presently being used by the refinery to store construction

materials. The overburden consists of a bouldery silt till which has been reworked and graded over as a result of former construction activities. A permeable gravel fill has been placed over the till south of the access road towards the creek.

A visible oil-stained area occurs in the general vicinity of the fenced compound situated between the warehouse and office building. The surface layer of the soil in this area is contaminated by organic compounds and some heavy metals. Elevated concentrations of some organics were detected in the groundwater under the oil-stained area.

Crushed and stockpiled drums lie along the east end of the pond bordering the north side of the warehouse and in two distinct piles northeast of the office building. There is little indication of the former drum contents. Oil and grease and a few heavy metals in the soil surrounding the drum piles exceeded background conditions but were below removal criteria.

Waste Disposal Site

This site is situated on top of a topographic ridge north of the refinery and covers an area of about 3.2 ha. The overburden consists of a blanket of fill materials and till over bedrock. The crown of the site consists of very permeable fill (largely construction waste in a matrix of silts, sands and gravels). Underneath this, and forming the main body of the site, lies a less permeable fill containing little waste products and/or till. Bedrock is close to the surface--slightly over 2 m below ground surface at the crown, about 3 m along the south periphery of the site and about 1 m along the access road.

The water table surface is quite variable over the site, but generally reflects the local topography. Several leachate springs are presently seeping from the west side of the crown. The largest is the most notable not only because of its size but because of its distinct white and yellowish appearance. Some other leachate springs contain floating

oil product. Excessive heavy metals were found in both the soil and groundwater at the leachate springs. Organic contamination of some areas of the crown adjacent to these springs were also detected.

Groundwater flow along the south and east flank of the site discharges to two prominent low-lying areas. A trench in the underlying materials immediately east of the crown collects surface runoff which seeps from the trench into the surrounding materials. High concentrations of nickel were detected in this trench.

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1 - INTRODUCTION

From 1973 until closure of the plant in 1976, the Newfoundland Refinery Company Limited operated the Come-by-Chance oil refinery. During this time two unregulated sites in the general vicinity of the plant were apparently used largely for the disposal of construction waste while a third site was used to store full and empty drums of refinery chemicals. Following field evidence suggesting potential pollution problems with all three of these sites, the Government of Newfoundland and Labrador Department of Environment (DOE) commissioned Acres International Limited (Acres) to carry out a hydrogeologic investigation. This investigation was designed to assess the impact of each site on the environment and recommend any remedial works that may be required to eliminate site hazards to the environment.

The tasks required for the study were subdivided into five phases as follows.

Phase I - Provide a hydrogeologic/geotechnical survey of each site in order to determine the scope of the subsequent testing/monitoring program.

Phase II - Undertake a testing/monitoring program designed to provide the required information needed to assess the extent of contamination and seepage of any chemicals from each site. This involved identifying the type and number of testing/-monitoring sites, installing the required instrumentation and performing these tests.

Phase III- Carry out a chemical sampling and analysis program designed to confirm the type, concentration and extent of any chemicals in the soil and groundwater.

Phase IV - Evaluate each site in terms of any chemicals identified, existing and potential off-site migration of these chemicals and the potential impact on the environment.

Phase V - Recommend any remedial action required to stabilize or contain each site and eliminate risk to the environment.

This report provides a summary of the investigation conducted between May and September, 1987. Chapter 2 describes the study area while Chapter 3 outlines the field methods used for the Phases I to III portion of the program. Based upon the hydrogeologic results obtained from the field program, the physical properties of each site are discussed in Chapter 4. The results of the chemical analyses and the criteria with which they were compared to are then described in Chapter 5. Chapter 6 follows with an assessment of the extent of contamination at each site (Phase IV) while Chapter 7 outlines the recommended remedial courses of action (Phase V).

With the exception of the work under Phase III (which was largely performed by DOE) all aspects of this investigation were conducted by Acres and its subcontractors.

2 - PHYSICAL SETTING

The Come-by-Chance refinery is located along the northeast shore of Placentia Bay between the villages of Come-by-Chance and Arnold's Cove. Figure 2.1 shows the location of the three sites under study. The two sites used as disposal areas are the Tank Farm (Site 1) and Waste Disposal Site (Site 3) while the Mill Building was the area used for storage of refinery chemicals. Only the Tank Farm site falls within the boundaries of the refinery proper.

All three sites are underlain by a continuous cover of till which blankets the area in the form of a gently rolling ground moraine. The prominent drumlinoid shaped hills in the area usually consist of a blanket of till over a bedrock core. According to Nolan, Davis & Associates Ltd. (1982), the underlying bedrock at Sites 1 and 2 is the Connecting Point Group consisting of Hadrynian graywacke and slate, with some sandstone and conglomerate. Lower Cambrian slate of the Bonavista, Smith Point and Brigus Formation or quartzite and conglomerate of the Random Formation underlies Site 3. Each formation or group is considered to be separated from each other by a fault. Bedrock dips steeply to the northwest in the study area.

2.1 - Site Descriptions

2.1.1 - Tank Farm (Site 1)

This site is situated at the south end of the refinery property near the crude oil storage tanks (see Figure 2.2) and occupies an area of about 0.6 ha. Access to the site is from the perimeter road running alongside the storage tanks. Apparently once used for the disposal of fill, construction waste materials and some domestic refuse, the materials comprising the site were dumped and graded over the original native till and peat deposits

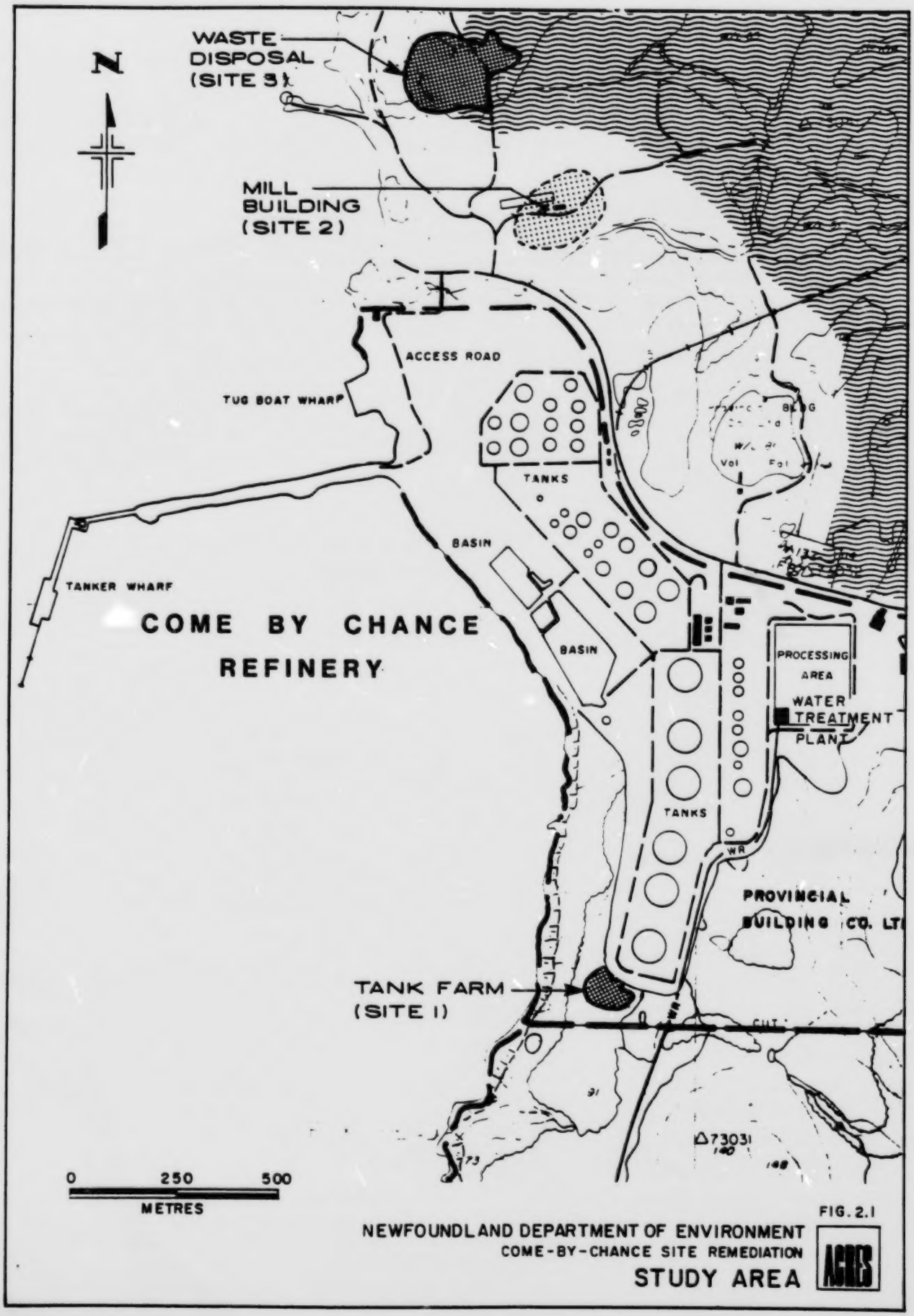

FIG. 2.1

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION
STUDY AREA

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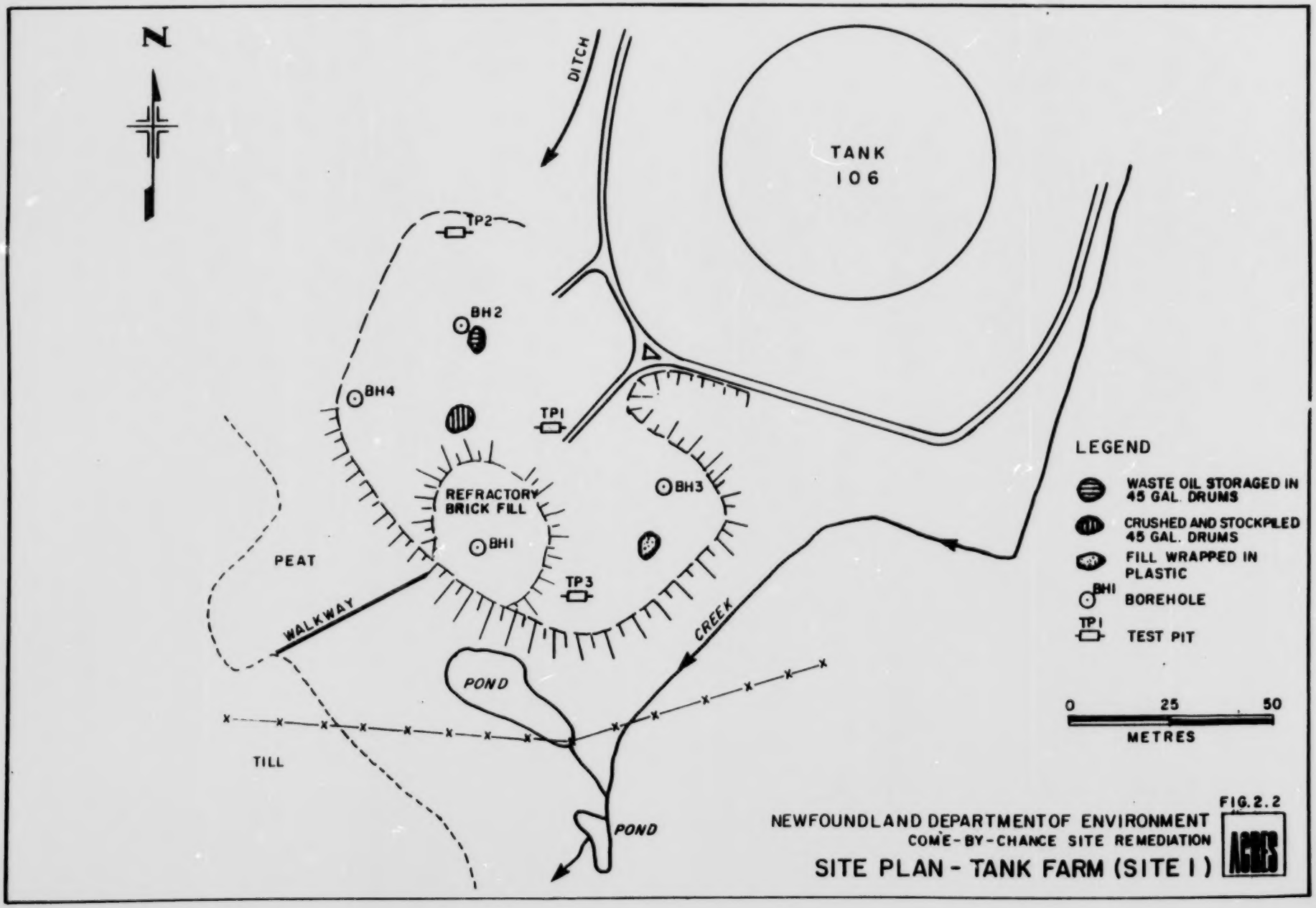

FIG. 2.2

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

SITE PLAN - TANK FARM (SITE 1)

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adjacent to the perimeter road. Fire drill activities are believed to have taken place at this site. Recently, refractory brick and excavated till from the refinery's new crude pumping station have been dumped onto the site, thereby adding to both the overall height and lateral extent of the fill.

The site is situated over a small topographic rise running southwest from the road entrance. Runoff from the south and east half of the site flows toward a small creek bordering the site. This creek drains runoff from the southern part of the refinery. Runoff from the north and west half of the site merges with drainage from a road ditch along the perimeter road. This, in turn, flows to the northwest along an ill-defined creek. Examination of the fill perimeter indicates that there does not appear to be any leachate springs flowing off-site.

Refractory brick forms the crown of the site at its southern end. The extent of this fill shown on the site plan represents its limits as of May, 1987. The DOE reports that most of this material has now been removed. Immediately north of this fill material lie crushed and stockpiled 45-gal drums which contain some solid residual product. Further north of this are upright 45-gal drums containing waste oil. These drums are not sealed and are subject to overflow during rainfall events. One drum in particular was observed to be leaking from a pinhole along its side. Some waste oil spillage was noted in the area immediately around these drums. East of the refractory brick is a plastic wrapped pile of fill which apparently is oil-soaked. No visible signs of leakage were evident from this pile. Apart from the drums and the plastic wrapped fill pile, the present site surface appears clean owing to the fact it consists of till recently excavated from the new crude pumping station. Patches of oil-soaked peat occur off-site to the southwest.

2.1.2 - Mill Building (Site 2)

This site is situated outside of and north of the refinery. Located adjacent to a creek draining Barrisway Pond to the east, the site is flat, low-lying and covers an area of about 2.5 ha (see Figure 2.3). Overburden consists of a bouldery till which has been graded over during the construction of the site buildings. A thin layer of reworked till and construction rubble lies near the buildings while on the south side of the access road a permeable gravel fill has been placed over the till between the road and the creek.

Access to the site is off the shoreline road running along its southern boundary. Vehicular traffic is restricted by gates at both the main access road and at the entrance to the Waste Disposal site, by a row of filled 45-gal drums between the two gates and by the creek itself.

The buildings on the site consist of a warehouse and an office building which were originally constructed for a proposed pulp and paper operation in 1967. Although never actually used for this purpose, the buildings and surrounding area were later used by the refinery for storing full and empty drums of refinery chemicals. Evidently, empty drums returning from the refinery were eventually crushed and stockpiled.

Presently there are three stockpiled drum areas; one at the east end of the pond running along the north side of the warehouse, and the other two northeast of the office building. Apart from some drums which were labeled as once containing fire extinguishing foam, there is little indication of the drum contents.

In and around the fenced compound between the warehouse and office building lies a visible oil-stained area and some scattered construction debris. During the field investigation a reddish

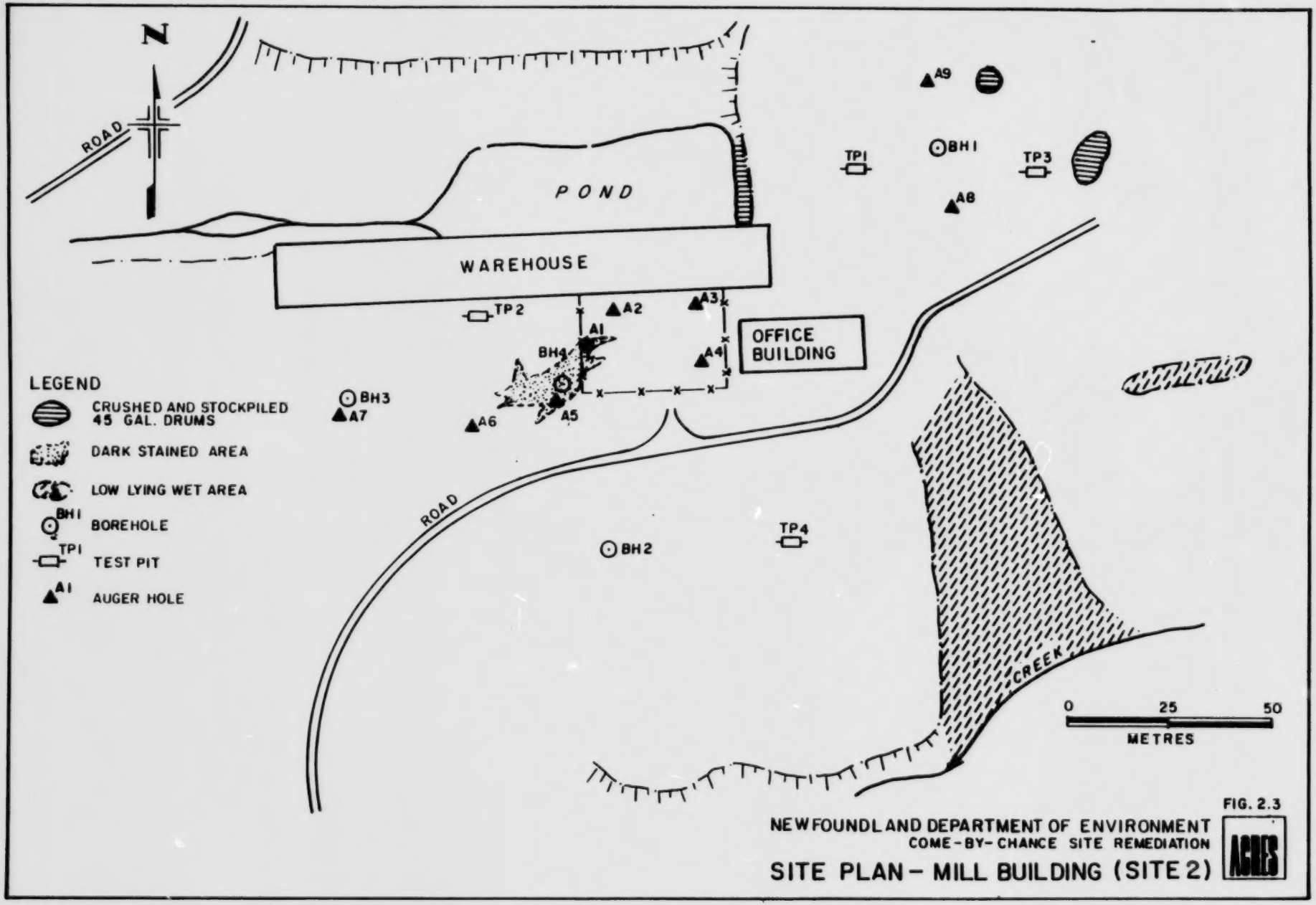

FIG. 2.3

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

SITE PLAN – MILL BUILDING (SITE 2)

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colored water was released from the thin cover of peat lying east of the oil-stained area when compressed by the passage of a vehicle. South of the fenced compound on the other side of the access road lies stockpiled equipment. The buildings are at present being used to temporarily store various construction products used in the refurbishing of the refinery.

2.1.3 - Waste Disposal (Site 3)

This site is situated about 300 m north of the Mill Building site. It was apparently used as an unregulated dump for the disposal of construction waste and domestic refuse during the initial construction of the refinery. Access is from a road originating off the shoreline road to the south. Vehicular traffic is controlled by a gate at the road entrance. Separated into two parts by the access road, the larger western part of the site covers an area of about 2.5 ha while the remaining eastern part covers an area of about 0.7 ha (see Figure 2.4).

The western part of the site straddles the southern end of a topographic ridge. About 100 m north of the site lies an abandoned rock quarry. Runoff flows steeply down several gullies along the western side of the site while drainage is more modest to the south and east. The north part of the site is flat to rolling. Several seeps are evident along the perimeter of the area but particularly along the upper edge of its western side. A small area at the very crown of the site is unvegetated and reveals a considerable amount of construction debris on the ground surface. A prominent leachate spring, white and yellowish in appearance, originates from the western edge of this unvegetated area. Other leachate springs immediately north of this flow off the west side of the site and contain a floating oil product in some of the runoff depressions. With the exception of the unvegetated area noted above, the western part of the site is vegetated by grasses

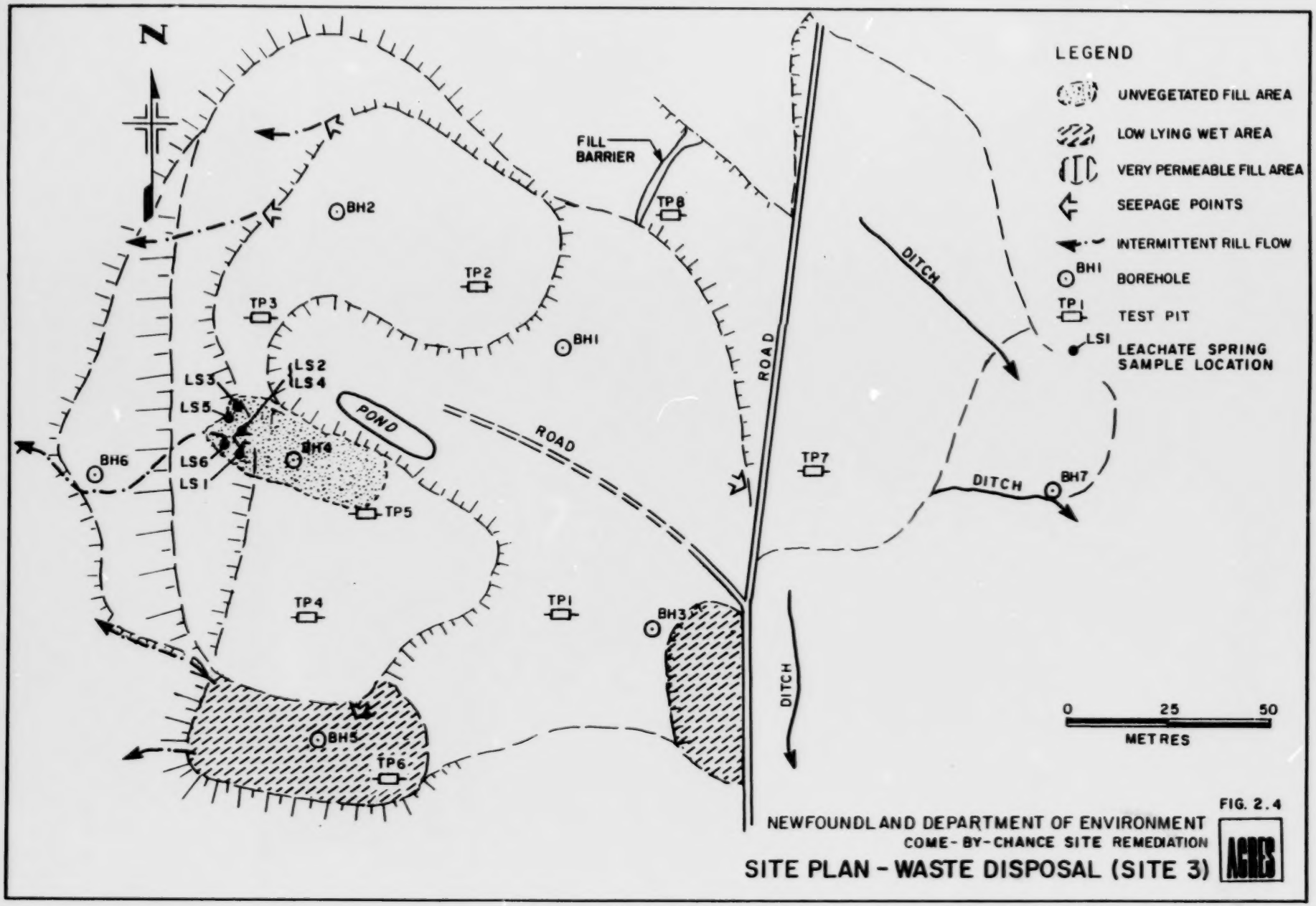

FIG. 2.4

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

SITE PLAN - WASTE DISPOSAL (SITE 3)

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and sedges. The most southerly and southeasterly sides of the area are low-lying and wet.

The eastern part of the site is largely unvegetated with the exception of its most eastern margin. Runoff through the site is directed by a prominent ditch to an ill-defined creek to the southeast. The lower eastern corner is flat, low-lying and wet with some crushed 45-gal drums partially exposed at the surface. A floating oil product was observed on a standing body of water in this area. The section immediately adjacent to the access road is presently being used for disposal of recently generated construction waste (largely insulation, sheet metal, wood and cardboard) and domestic refuse from the refinery. These materials are occasionally burned to reduce volume.

3 - FIELD PROGRAM

3.1 - Scope

Field work for the tasks under Phases I and II (see Chapter 1) was conducted during May, 1987. It involved an initial reconnaissance of each site followed by augering, testpit excavation, borehole drilling, installation and development of groundwater monitoring wells, water level monitoring and in-situ hydraulic conductivity testing at all three sites. Phase III tasks were undertaken from June to August, 1987. These included continuation of both the water level monitoring and well development, in addition to chemical testing and analysis of surface waters and groundwater. A description of each task follows.

3.2 - Methodology

3.2.1 - Augering

Shallow soil samples were collected by augering at nine locations surrounding the Mill Building site. This form of sampling was carried out at this latter site in order to examine the vertical extent of contamination in the surface layer owing to visible (oil-stained area) and potential (crushed and stockpiled drums) spillage of contaminants.

Two samples were taken for chemical analysis from each location; a sample of the surface layer to a depth of about 5 cm followed by a sample of the underlying layer to the depth of refusal--usually about 20 cm. The hole was dug either with an auger bit or, in more difficult locations, with a hand-pick. Cuttings retained in the auger bit were examined, logged in the field and then split and stored, in duplicate, using

- pre-cleaned glass jars with foil wrapped lids, and
- foil wrap sealed in plastic bags.

This procedure was also followed when using the hand-pick with the exception that the side walls of the hole were carefully scraped away using a stainless steel trowel, prior to sample collection. All tools used for soil sampling were steam cleaned between locations and, where warranted, between sampling horizons to prevent cross-contamination. Details of the auger logs are provided in Appendix A. Note that the general order of the numbering scheme used for the soil samples is such that increasing numbers correspond to samples taken at increasing depth. This system applies to soil samples obtained by augering, testpitting or borehole drilling.

3.2.2 - Testpit Excavation

A total of 15 testpits were excavated over the three sites at depths ranging from 0.9 to 3.2 m. Testpits enabled more detailed examination of the soil horizons and the collection of soil samples from deeper layers. All excavating was done using a track-mounted CAT 225 backhoe from Goobie Rentals and Contracting Limited of Queen's Cove, Newfoundland.

Each testpit was examined and logged in the field, noting the thickness of undisturbed or disturbed horizons, the vertical extent of any contaminated layers and indications of the position of the water table or permeable layers.

After the inspection, soil samples were selected and taken, in duplicate, for chemical analysis. Samples were obtained by scraping away a part of the side wall of the pit and then splitting and storing the sample in the same manner as for the auger holes.

Before backfilling, a monitoring well was installed in 11 of the 15 testpits. Each monitoring well was constructed using either 3.1 or 3.7 m lengths of 38 mm nominal diameter ABS pipe. The lower 1 m of the pipe was diagonally cut with a hacksaw and the end sealed with a friction fit cap. While the pipe was held in position along the side wall, the testpit was backfilled in such a manner as not to introduce obviously contaminated soil into a deeper horizon. Details of the testpit logs are summarized in Appendix A.

3.2.3 - Borehole Drilling

Fifteen boreholes were drilled over the three sites, seven at the Waste Disposal site and four at each of the Tank Farm and Mill Building sites. Boreholes provided information on the soil characteristics through standard penetration tests, sample collection and, following the installation of a monitoring well in each borehole, in-situ hydraulic conductivity tests. Most boreholes were drilled to a depth of about 2.6 m in order to reach the water table.

All drilling was carried out using a trailer or track-mounted BBS-15 supplied and operated by Atlantic Geodrilling Limited of St. John's, Newfoundland. The boreholes were driven or wash-bored using BW or NW casing. Wash boring was not used at either the Waste Disposal or Tank Farm sites and its use was minimized where possible at the Mill Building site.

At each borehole, standard penetration tests were conducted and soil samples collected using a 35-mm ID split spoon sampler at intervals of 0.76 m. All soil samples were examined and logged in the field and then stored by wrapping in foil and sealing in a plastic bag. The split spoon sampler was steam cleaned between sampling horizons to prevent cross contamination. Details of the borehole logs are given in Appendix B.

3.2.4 - Monitoring Well Installation

A groundwater monitoring well was installed in each borehole upon completion of the soil logging. Each well was constructed out of 41-mm ID Schedule 40 PVC Timco^{R} casing with flush threaded joints. All intake screens consisted of either 6 or 10 slot screens in 1.5 m lengths. A friction fit slip cap was used to seal the bottom end of each well. All well screens were packed with silica sand to an elevation at least 0.3 m above the top of the screen. The sand was poured around the annulus and tamped into place as the temporary steel casing was withdrawn from the borehole. Bentonite powder (Mill Building site) or pellets (Tank Farm and Waste Disposal sites) were then placed above the sand to within 0.2 to 0.3 m of the ground surface. The remainder of the annulus was cemented off during the installation of a 0.9 m length of steel casing with threaded cap to protect the top end of the monitoring well. At the ground surface the cement was extended to a radius of about 0.3 m from the center of each monitoring well to direct surface water away from the borehole and thus prevent infiltration. The elevation of the ground and top of casing of each monitoring well was later surveyed by Acres. The top of casing for Borehole 1 at each site was used as the local benchmark for that site. A summary of the monitoring well details is provided in Appendix B.

3.2.5 - Water Level Monitoring and Hydraulic Conductivity Testing

Following the completion of each monitoring well, routine water level measurements were taken in order to establish the return to equilibrium conditions. All water levels were monitored with an electric sounding tape equipped with a stainless steel probe. Appendix C provides a summary of all water level measurements taken from the borehole and testpit monitoring wells. Once a static water level condition was confirmed by a series of

readings on a well, an in-situ hydraulic conductivity test was performed. The test involved pumping out the volume of water in the well bore using either a hand suction pump and tygon tubing, or rapidly bailing with a stainless steel bailer. The recovery of the water level was then monitored over time. This test was conducted on all monitoring wells except Boreholes 5 and 6 at the Waste Disposal site which did not reach static conditions during the Phase II portion of the program. The test results were analyzed by the Hvorslev method (1951) and are summarized for each site in Table 3.1.

3.2.6 - Monitoring Well Purging and Water Sampling

Following the hydraulic conductivity testing, a series of well purgings were carried out on each well to ensure that water samples, taken for groundwater chemical analysis, were representative of the in-situ groundwater conditions. This involved the removal of at least six well bore volumes from each well prior to the collection of water samples. The exception to this is some of the wells at the Waste Disposal site. Due to the general lack of precipitation during the monitoring period and the low hydraulic conductivity around some of the well sites, only three bore volumes were taken from Boreholes 1, 3, 5 and 6 to ensure that a water sample would be collected from each well within the timeframe of the study. Water was removed using either a hand suction pump and tygon tubing or a stainless steel bailer. The pump and tubing or bailer were washed between wells to avoid cross-contamination. The initial well purgings up to May 27, 1987 were performed by Acres with the remaining purging sessions to early August, 1987 conducted by the DOE. A summary of the purgings undertaken at each borehole is provided in Appendix D.

TABLE 3.1

HYDRAULIC CONDUCTIVITY SUMMARY

Site	Borehole No.	Hydraulic Conductivity (cm/s)
TF	1	3.1×10^{-6}
	2	7.4×10^{-4}
	3	1.2×10^{-3}
	4	5.2×10^{-6}
MB	1	5.0×10^{-6}
	3	6.1×10^{-4}
	4	6.3×10^{-5}
WD	1	2.8×10^{-7}
	2	1.4×10^{-3}
	3	1.3×10^{-5}
	4	1.2×10^{-4}
	7	1.3×10^{-5}

Analyzed by Hvorslev (1951) method

After the monitoring wells had been purged, groundwater samples were collected from each well for chemical analysis. Samples were collected by the DOE from July to September, 1987 using either a PVC bailer or a stainless steel bailer. For each borehole, the sampling procedure consisted of the following.

(a) Temperature, pH and specific conductance were determined in the field using electrodes and meters and an unfiltered 125-mL water sample.

(b) An unfiltered 500-mL sample for phenols was collected in a precleaned, pre-purged clear glass bottle, preserved with both copper sulfate and concentrated phosphoric acid to a pH less than 2 and then cooled.

(c) Three 250-mL samples for metals were collected in polyethylene bottles and later filtered and preserved in the laboratory with nitric acid to a pH less than 2.

(d) A 1-L sample for oil and grease was collected in a glass bottle, preserved with sulfuric acid to a pH less than 2 and then cooled.

(e) A 250-mL sample for alkalinity and major ions was collected in a polyethylene bottle and later filtered in the laboratory.

In order to avoid cross-contamination, the sampling device was cleaned between boreholes in the following manner.

(a) The bailer was immersed and scrubbed in a container containing a soapy water solution and then rinsed with distilled water.

(b) Following this, the bailer was immersed in a second container consisting of a 10% vol/vol solution of acetone in water.

(c) The bailer was then placed in a third container of distilled water for a final rinsing.

4 - HYDROGEOLOGIC CONDITIONS

4.1 - Tank Farm

The location of the four boreholes and three testpits completed at the Tank Farm is shown in Figure 2.2. The overburden comprising the site consists of fill underlain by glacial till adjacent to the perimeter road and by peat along the southwest part of the site. The fill materials vary from a clayey sand (refractory brick) around Borehole 1 to a variable mixture of silt, sand and gravel over the rest of the site. The partially vegetated portions of the site adjacent to the road appear to contain more construction waste than the remaining areas toward the southwest, as given by its surface expression and the materials encountered at Testpit 2. This, however, is masked by fill (excavated till) from the new crude pumping station which has recently been deposited over the site. Soil samples from Boreholes 2 and 3 also revealed the presence of permeable sand layers which were stained black by an oil product and/or fire drill activities. The physical appearance of the soil samples from Boreholes 1 and 4 and Testpits 1 and 3 all indicated fairly clean fill materials along the southwest margin of the site. Bedrock was only encountered at Borehole 3, at a depth of slightly less than 4 m below ground surface.

Water level measurements taken from May to September, 1987 indicated fairly uniform water levels over time in both the very permeable materials surrounding Borehole 3 and Testpit 2 and the underlying peat at Borehole 4. This is in comparison to an overall decline of about 0.5 m which was observed at Boreholes 1 and 2 over this same period of time. Although not measured, these latter two boreholes would have likely shown some recovery by late September as a result of rainfall during that period. The depth to the water table is variable over the site but generally reflects the overall topography. The water table varied over the site from about 3 m below ground surface at Boreholes 1 and 2 to about 1 m at Testpit 2 on September 15.

Figure 4.1 is a site map showing the water table surface on September 15, 1987. The water table is highest around the refractory brick at the south end of the site, with groundwater flow spreading radially away from this mound. In keeping with the general topography of the peat southwest of the refractory brick, a groundwater divide has been assumed in this area. Horizontal hydraulic gradients are a steep 0.1 between the refractory brick and the small pond to the south, declining to about 0.02 towards Testpit 2. The lower hydraulic gradient along the north and east margins of the site is felt to correspond to both the small surface slope of the fill and to some extent the more permeable nature of the fill in this area.

The hydraulic conductivity values determined for this site (see Table 3.1) indicate that a value of about 4×10^{-6} cm/s is typical of the refractory brick and underlying peat. A value of about 1×10^{-3} cm/s would appear to be more appropriate for the permeable areas of the fill considering the rapid recovery of the water levels at Boreholes 2 and 3 during the bail testing and observations made during the excavation of Testpit 2 (high rate of inflow). Using these values, the average groundwater velocity was determined along two directions from the refractory brick--one toward Testpit 2 and the other toward the pond to the south. Estimates of the average groundwater velocity provide a general indication of the rate nonreactive contaminants may move off-site due to advection--the dominant transport process for the soil conditions at all three sites. The results are summarized in Table 4.1. Porosity values of 0.1 and 0.3 were assumed for the refractory brick and permeable fill materials, respectively. The results indicate travel times of about 150 years from the crown to the base of the refractory brick and about 20 years to the pond. Although these travel times from the refractory brick are fairly long, the projected 2-yr travel time from the upgradient end of the permeable fill to the north or east margins of the site is quite short. Hence, it is this part of the site which is the area of immediate concern regarding off-site migration of any contaminants.

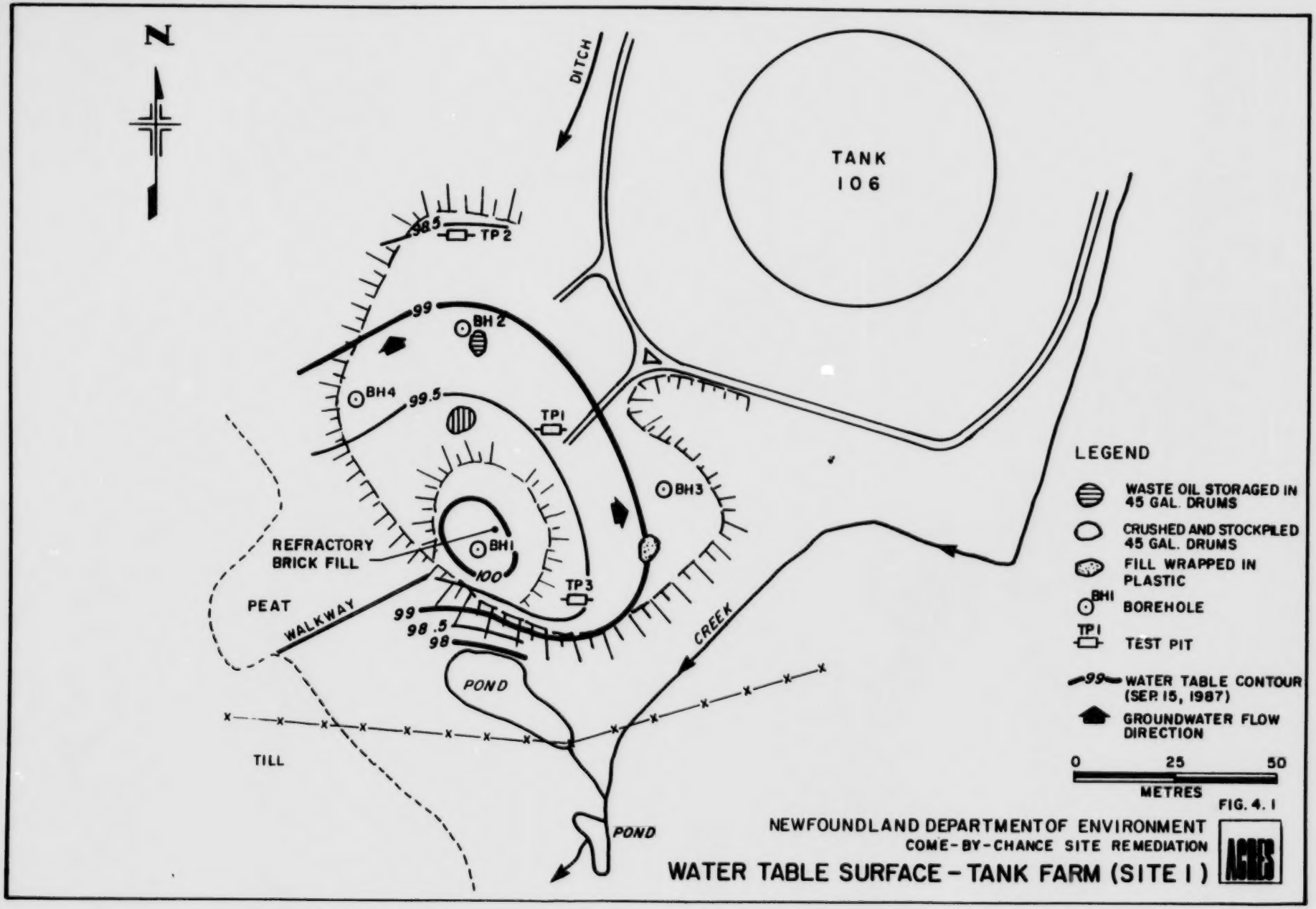

FIG. 4.1

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

WATER TABLE SURFACE - TANK FARM (SITE 1)

ACRES

TABLE 4.1

GROUNDWATER VELOCITY - TANK FARM SITE

Flow Direction	Hydraulic Gradient	Hydraulic Conductivity (cm/s)	Assumed Porosity	Average Velocity (cm/s)	Estimated Travel Time (yr)
1. Between crown of refractory brick fill and					
(a) pond	0.1	4×10^{-6}	0.1	4×10^{-6}	20
(b) BH4 & TP1	0.02	4×10^{-6}	0.1	8×10^{-7}	150
2. Between BH4 & TP1 and TP2	0.02	1×10^{-3}	0.3	6.7×10^{-5}	2

4.2 - Mill Building

Figure 2.3 shows the location of the nine shallow soil samples collected around the site. The four boreholes and four testpits completed at this site are also shown on this diagram.

The overburden consists of a compact to very dense glacial till containing a heterogeneous mixture of silt, sand and gravel with a trace of clay. Most of the exposed till has been graded over as a result of former construction activities on the site. Reworked till and rubble occurs as a thin layer adjacent to the buildings while a permeable gravel fill about 1 m thick has been spread over the area between the access road and creek. Bedrock was only encountered at Testpit 2 at a depth of about 2 m below ground surface. Some outcrops of bedrock occur along the north side of the warehouse. The water levels measured in the monitoring wells from May to September, 1987 all showed a consistent decline of about 0.5 m through July and a return to late spring/early summer levels by late September. The water table is fairly close to the ground surface. Using the September 24 readings, the water table varied over the site from about 0.6 m below ground surface (bgs) at Boreholes 1 and 3, about 0.3 m bgs at Borehole 2 and about 0.2 m bgs at Borehole 1.

Figure 4.2 shows the water table surface on September 24, 1987. As can be seen from this map a groundwater mound occurs below the oil-stained area with groundwater flow largely directed away from this mound toward the pond to the north and the creek to the south. The explanation for this mound lies in the fact that the oil-stained area corresponds to a shallow surface depression which collects and temporarily stores runoff on the south side of the warehouse, thus promoting infiltration. An additional monitoring well would be required near the office building to confirm the shape of the eastern side of the mound. Horizontal hydraulic gradients from the groundwater mound vary from about 0.06 toward the pond to about 0.02 toward the creek. Northeast of the office building near Borehole 1 the groundwater flow direction appears

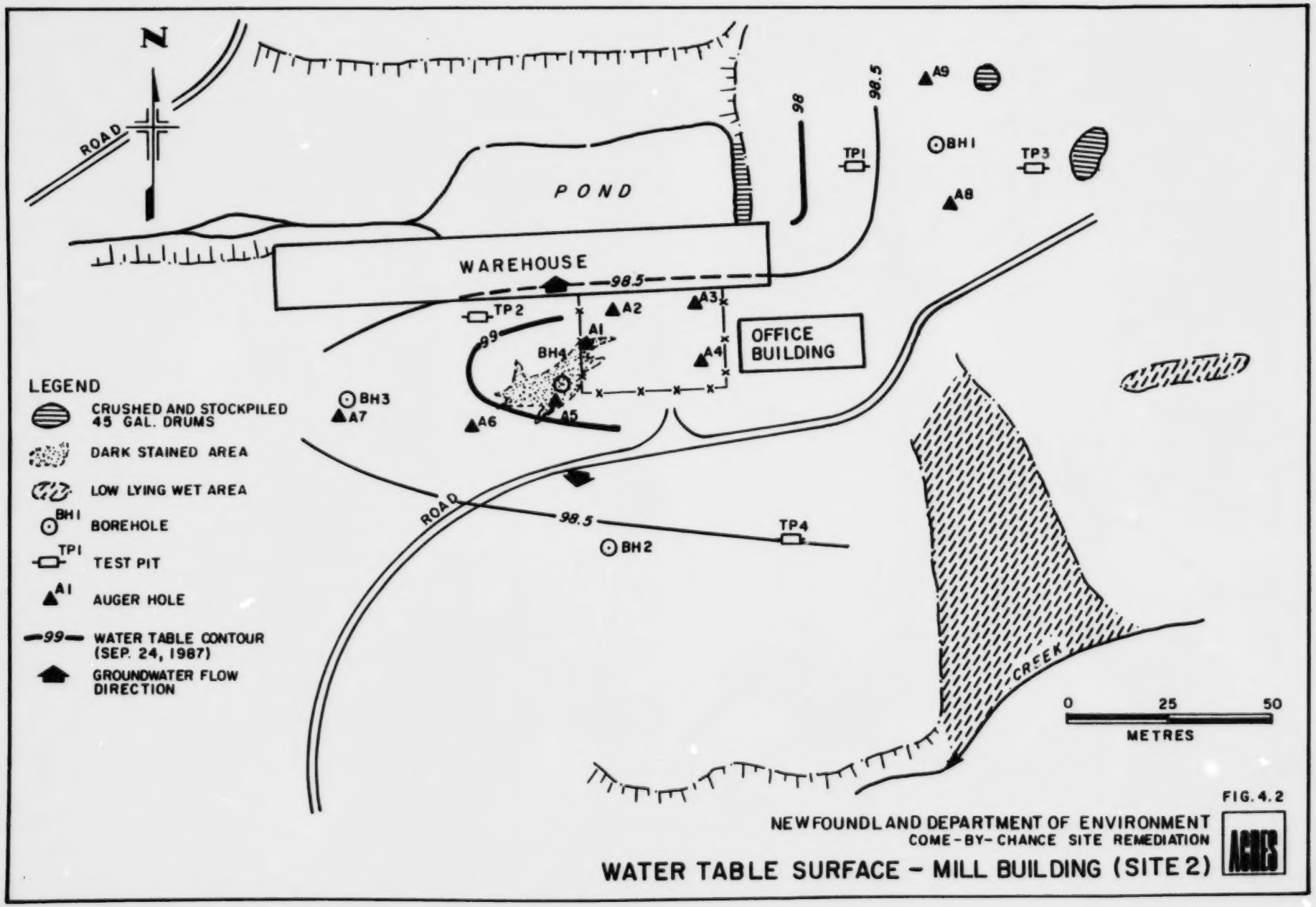

FIG. 4.2

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

WATER TABLE SURFACE - MILL BUILDING (SITE 2)

to be toward the pond on the north side of the warehouse. The hydraulic gradient between Borehole 1 and the pond is about 0.03.

The hydraulic conductivities calculated for the till at this site (see Table 3.1) range from 5.0×10^{-6} cm/s to 6.1×10^{-4} cm/s. The lower value is considered more representative of the site as a whole since the higher value obtained from Borehole 3 corresponds in part to sand lenses within the till. The very rapid return to equilibrium conditions at Borehole 2 did not enable a calculation to be made for the permeable gravel fill overlying the till. A value of about 1×10^{-3} cm/s has been assumed for this material. Using these hydraulic conductivity figures and the previously noted hydraulic gradients, an average groundwater velocity was calculated for each of the main flow directions mentioned (the pond and creek). A porosity value of 0.1 was assumed for the till while a value of 0.3 was taken for the gravel fill. The results of these calculations are tabulated in Table 4.2.

Estimated travel times are also provided in Table 4.2. Under the steeper hydraulic gradient and shorter distance from the mound to the pond, it is estimated that groundwater travel time to the pond is about 4 years. Although the fill on the south side of the access road is very permeable, the longer distance to the creek and shallow hydraulic gradient results in a combined travel time of about 12 years from the mound to the creek. The low hydraulic conductivity obtained at Borehole 1 indicates that groundwater from the area around the stockpiled drums will not have migrated any appreciable distance.

TABLE 4.2

GROUNDWATER VELOCITY - MILL BUILDING SITE

Flow Direction	Hydraulic Gradient	Hydraulic Conductivity (cm/s)	Assumed Porosity	Average Velocity (cm/s)	Estimated Travel Time (yr)
1. Between groundwater mound and					
(a) pond	0.06	6×10^{-5}	0.1	3.6×10^{-5}	<4
(b) access road	0.02	6×10^{-5}	0.1	1.2×10^{-5}	7
2. Between access road and creek	0.02	1×10^{-3}	0.3	6.7×10^{-5}	5
3. Between BH1 and pond	0.03	5×10^{-6}	0.1	1.5×10^{-6}	100

4.3 - Waste Disposal Site

Figure 2.4 displays the location of the seven boreholes and eight testpits completed on this site. The materials forming the very crown of the site consist largely of a very loose to loose mixture of construction waste (wood, strapping, wire, scrap metal) and domestic refuse in a matrix of silts, sands and gravels. The construction waste appears more abundant within the fill at the north half of the crown while the matrix sediments appear more prevalent at the south end. Below this crown and forming the main body of this site is a very loose to loose fill composed of variable amounts of silt, sands and gravel with a trace of clay. The fill in turn is mainly underlain by peat and/or a compact to dense glacial till containing a heterogeneous mixture of silt, sands and gravels and a trace amount of clay. In Borehole 4 and several testpits, bedrock was encountered below either the fill or till at depths ranging from about 1 m (Testpits 7 and 8), to slightly over 2 m at the crown of the site to about 3 m at Testpit 6.

Water levels measured from May to September, 1987 indicate that the boreholes or testpits completed in more permeable materials declined by only 0.2 to 0.4 m over the measurement period while those completed in the less permeable soil dropped by at least 0.8 m. Most of the monitoring wells were recovering at the time of the last water level reading on September 24, 1987 with the highest response in those wells completed in lower permeable materials. This pattern of fluctuation over the summer partly reflects the well purgings conducted on the boreholes and the nature of the installation of the testpit wells.

Using the September 24 water level readings, the depth to the water table varied over the site from less than 1 m (range 0.4 to 0.9) along the east flank of the site, to about 1.3 over the north half of the crown, between 0.6 and 1.7 over the south half of the crown to more than 2.4 around Borehole 5. In comparison to Borehole 5, the water table is high at Testpit 6. This suggests that the head difference

between the two wells is due to temporary readjustments in the water level. The water level may be elevated in Testpit 6 due to infiltrating surface waters while the water level in the low permeable materials around Borehole 5 is expected to slowly recover over time. Fluctuations in all other adjacent borehole and testpit water levels appear to be consistent with each other.

The water table surface on September 24, 1987 is displayed in Figure 4.3 and in general reflects the topography of the site. An elongated mound occurs along the west central side of the crown with groundwater flowing radially away from this area of high head in all directions, but primarily to the west and east. The leachate springs seeping out of the west side of the crown are consistent with the occurrence of a very permeable fill overlying less permeable materials. The decline in head along the east flank of the site leads to the situation where the east margin of the crown is dry to partially saturated as flow migrates downward into the underlying fill or till. The trench between the two halves of the crown lies within these underlying materials and serves to collect surface runoff and permit seepage to the area immediately surrounding it.

Flow off the east flank of the site discharges around the low-lying area between Borehole 3 and the access road. South of the crown the water table slopes steeply towards the low-lying area below it due to the sharp change in topography. Some seepage from the south margin of the crown feeds this low-lying area and appears to form a perched water table. Horizontal hydraulic gradients vary from about 0.015 in the permeable materials forming the crown of the site to about 0.04 along the east flank. Gradients along the west and south flanks are quite steep--about 0.3.

The hydraulic conductivities calculated for the site (see Table 3.1) are quite variable, ranging from a low of 2.8×10^{-7} cm/s to a high of 1.4×10^{-3} cm/s. The lower value is considered as representative of the underlying basal till while the higher value corresponds to the

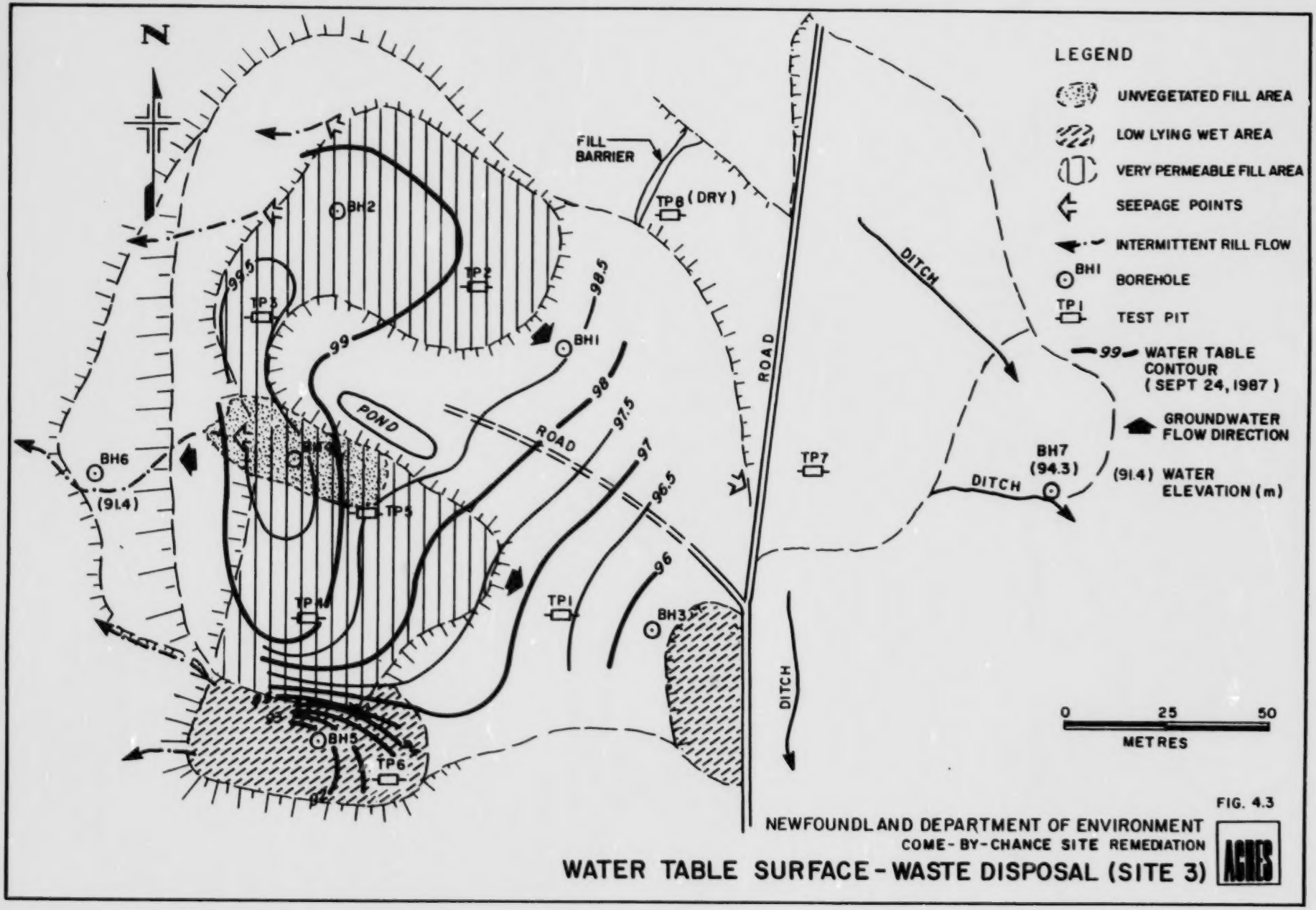

FIG. 4.3

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WATER TABLE SURFACE - WASTE DISPOSAL (SITE 3)

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very permeable materials forming the north half of the crown. Note that this latter value is supported by observations made during the excavation of Testpits 2 and 3 (high rate of inflow). A hydraulic conductivity of about 1×10^{-5} cm/s (Boreholes 3 and 7) appear to be representative of the fill materials comprising the eastern flank of the site.

Using both the hydraulic gradient and hydraulic conductivity data, groundwater velocities were calculated for several flow directions off the site. Table 4.3 presents the results of these calculations. The travel time for groundwater to migrate from within the northern half of the crown is expected to be no greater than 2 years while about 3 years is needed for groundwater to reach the leachate spring west of Borehole 4. Travel times for groundwater flow along the eastern flank of the site is much longer owing to the lower hydraulic conductivity of these materials. Due to the low topographic relief of the fill on the east side of the access road, groundwater flow is expected to be slow and directed locally toward either the ditches or the standing water body near Borehole 7.

TABLE 4.3

GROUNDWATER VELOCITY - WASTE DISPOSAL SITE

Flow Direction	Hydraulic Gradient	Hydraulic Conductivity (cm/s)	Assumed Porosity	Average Velocity (cm/s)	Estimated Travel Time (yr)
1. Between BH1 and adjacent leachate spring	0.03	1×10^{-4}	0.3	1×10^{-5}	3
2. From center to eastern edge of the north half of crown	0.015	1×10^{-3}	0.3	5×10^{-5}	2
3. Between trench and BH3	0.04	1×10^{-5}	0.1	4×10^{-6}	50

5 - CHEMICAL ANALYSIS

5.1 - Scope

A chemical screening process was applied to all 3 sites in order to test for certain inorganic and organic constituents which either could be, or are, indicative of waste products. The process consisted of performing certain groups of chemical analyses on the soil and water samples collected during the field investigation and then comparing the results to selected criteria.

The chemical analyses comprising each of these groups and the reasons for using them are outlined below.

Group 1 - Oil and Grease--used as an overall indicator of the presence and quantity of hydrocarbons from a wide range of sources.

Group 2 - Phenolics--used as a more specific indicator of organic contamination.

Heavy Metals--eight heavy metals (arsenic, cadmium, chromium, copper, lead, nickel, vanadium and zinc) were selected as being commonly associated with petroleum refining.

Group 3 - (a) Soils only

Specific organic compounds -

(i) Chlorinated Aliphatic Hydrocarbons--used as an indicator of presence of halogenated hydrocarbons

(ii) Chlorobenzenes--used as an indicator of the presence of chlorinated solvents

(iii) Ethanolamines--associated with petroleum refining

(iv) PAHs--possibly associated with tank bottoms, or fire drill activities

(v) PCBs--used only to confirm its presence or absence; possible sources would be dielectric fluids (e.g. transformer oils) or hydraulic fluids.

(b) Water Only

Major ions--used to classify types of water and, in the case of anions, may be an indicator of construction waste ($SO_4^{=}$), sewage (NO_3^{-}) or a nonspecific source of contamination (Cl^{-}).

General Parameters - pH and specific conductance used as indicators of general water quality.

A complete summary of the testing rationale and the method of analysis for each constituent is provided in Appendix E. All soil and water samples were forwarded to the Environmental Protection Service (Environment Canada) laboratory in St. John's, Newfoundland for chemical analysis. The bulk of the analyses were performed at this facility. Some of these soil samples were later sent to the Acres laboratory in Niagara Falls, Ontario for analysis of selected organic compounds. A brief description of the number of soil and water samples analyzed under each group follows.

5.1.1 - Soil Analyses

Of the 105 soil samples obtained from either boreholes, testpits, auger holes or the soil surface in selected areas, 74 were analyzed for oil and grease (Group 1). A subset of 47 of these

samples were further analyzed for phenolics and heavy metals under Group 2 while one to two samples from each site were analyzed for the Group 3 organic compounds.

A summary of the soil sample locations corresponding to these various chemical analyses is provided in Table 5.1. The samples selected for the above analyses were considered to provide representative coverage of the soil conditions encountered at each site. The complete set of soil test results is provided in Appendix F.

5.1.2 - Water Analyses

In general, all three groups of chemical parameters were tested for on 15 groundwater samples and for five surface water samples. The exceptions to this were the water samples collected toward the end of the field investigation. Three of the groundwater samples from the Waste Disposal site (Boreholes 1, 3 and 5) were essentially only analyzed under Group 1 while two leachate spring samples from the same site were only analyzed for the heavy metals part of the Group 2 parameters.

A summary of the water type and sample locations is provided in Table 5.2. Appendix G summarizes all of the test results for water.

5.2 - Criteria Used

5.2.1 - Soils

At the present time there are few cleanup standards with which to compare soil chemistry results. There are no approved federal or provincial guidelines and only a limited number of international

TABLE 5.1

SOIL SAMPLES ANALYZED FOR VARIOUS PARAMETERS

Site	Sample Location	Sample No.	Oil & Grease	Phenolics and Metals	Organic Scan	Chloro-benzenes	PCBs	PAHs	Ethanol-amines
Tank Farm	BH1	-4	*	*					
	BH2	-1	*	*		*			
		-2,-3,-4	*	*					
	BH3	-2,-5	*	*					
	BH4	-2	*	*	*			*	
	TP1	-1	*		*				*
		-2	*						
	TP2	-1	*	*			*		*
	TP3	-1,-2	*						
	SS (TP2)		*	*					
	BK1		*	*					
	BK2		*	*					
Mill Building	A1	-1	*						
		-2	*						*
	A2	-1,-2	*						
	A3	-1,-2	*						
	A4	-1	*	*	*		*		*
		-2	*	*					
	A5	-1	*	*	*	*		*	
		-2	*	*					
	A6	-1,-2	*	*					
	A7	-1,-2	*						
	A8	-1,-2	*						
	A9	-1	*						
	BH3	-2	*	*					
	BH4	-2	*	*					
	TP2	-1,-3,-4	*						
		-2	*	*				*	
	TP3	-1,-2	*	*					
		-3	*						
	TP4	-1	*	*					
		-2	*						

Table 5.1
Soil Samples Analyzed for Various Parameters - 2

Site	Sample Location	Sample No.	Oil & Grease	Phenolics and Metals	Organic Scan	Chloro-benzenes	PCBs	PAHs	Ethanol-amines
Waste Disposal	BH1	-2	*	*					
	BH2	-3,-4	*	*					
	BH3	-1,-4	*	*					
	BH4	-1	*	*				*	*
		-2	*	*					
	BH5	-4	*	*					
	BH6	-2,-3,-4	*	*					
	BH7	-2,-3,-4	*	*					
	TP1	-1,-2	*						
	TP4	-1	*	*					
	TP5	-1	*						
		-2	*		*		*		*
		-3	*	*		*			
		-4			*				
	TP6	-1,-2	*						
	LS	-1,-2,-3, -4,-5,-6	*	*					
	BK		*	*					

A - Auger hole
BH - Borehole
TP - Testpit
LS - Leachate spring
BK - Background
SS - Surface sample

TABLE 5.2

WATER SAMPLES ANALYZED FOR VARIOUS PARAMETERS

Site	Sample Location	Sample Type	Oil & Grease	Phenolics	Metals	Major Ions and General Parameters
Tank Farm	BH1	gw	*	*	*	*
	BH2	gw	*	*	*	*
	BH3	gw	*	*	*	*
	BH4	gw	*	*	*	*
Mill Building	BH1	gw	*	*	*	*
	BH2	gw	*	*	*	*
	BH3	gw	*	*	*	*
	BH4	gw	*	*	*	*
	Pond	sw	*	*	*	*
Waste Disposal	BH1	gw	*	*		
	BH2	gw	*	*	*	*
	BH3	gw	*			
	BH4	gw	*	*	*	*
	BH5	gw	*			
	BH6	gw	*	*	*	*
	BH7	gw	*	*	*	*
	LS5	gw			*	
	LS6	gw			*	
	Trench	sw	*	*	*	*
	Bog(BH7)	sw	*	*	*	*
	Quarry	sw	*	*	*	*
	Water Supply	sw	*	*	*	

BH - Borehole
LS - Leachate spring
gw - groundwater
sw - surface water

standards. Therefore, in the absence of such criteria the two references used were:

(i) an Ontario Ministry of the Environment (OMOE, 1987) internal draft guideline entitled 'Guidelines for the Decommissioning of Sites in Ontario', and

(ii) a cleanup standard developed by the Government of the Netherlands (Moen, et al, 1985) and adopted for use by the Quebec Ministry of the Environment (R. Rhine, personal communication).

Although the Netherlands' standard is the more comprehensive and stringent of the two documents, it has only been used in this report for those parameters not covered in the OMOE guideline. This therefore results in a version in which the Netherlands standard has been used to compare phenolics (Group 2) and all of the organics compounds except ethanolamines under Group 3, while the OMOE guideline has been used to assess oil and grease (Group 1) and the eight heavy metals under Group 2. A guideline for ethanolamines was not available.

The combined version of the above two guidelines is summarized in Table 5.3. Note that the Netherlands' standard also provides reference background values and a further investigation category in addition to the cleanup category.

Soil samples were also collected at each site for the purposes of establishing background conditions. At both the Tank Farm and Waste Disposal sites a surface soil sample was collected offsite, while at the Mill Building site, soil sample BH3-2 was used for this purpose.

TABLE 5.3

CLEANUP GUIDELINES FOR SOILS

Parameter	OMOE Criteria (ppm dry weight)	Remarks
Oil and Grease	10,000 20,000	Fresh oil Weathered oil
Arsenic	50	
Cadmium	8	
Chromium (total)	1,000	
Copper	300	
Lead	1,000	
Nickel	200	
Vanadium	250	
Zinc	800	

Parameter	Netherlands Criteria (ppm dry weight)		
	Reference Background Value	Further Investigation Required	Cleanup Required
Phenolics	0.02	1	10
Chlorinated Aliphatic Compounds (total)	0.1	7	70
Chlorobenzenes (total)	0.05	2	20
Polychlorinated Biphenyls (total)	0.05	1	10
Polycyclic Aromatic Hydrocarbons (total)	1	20	200

5.2.2 - Water

Although it is unlikely that surface waters or groundwaters at any of the three sites will ever be used as a source of drinking water, a drinking water standard provides a practical basis to assess whether these waters may have been impaired. Therefore the "Canadian Drinking Water Quality Guideline" (Canadian Council of Resource and Environment Ministers, 1987) was used to compare the following chemical test results for water.

- Phenolics and most of the heavy metals under Group 2.
- The anions and pH under Group 3.

The criteria for these constituents is listed in Table 5.4.

In the absence of a criteria for oil and grease, nickel and vanadium a comparison with background conditions was made. The remaining cations and general water quality parameters under Group 3 are not particularly indicative of contamination by themselves.

A monitoring well which could be used for establishing overall background water quality conditions for all three sites was not specifically installed during this study. Therefore the monitoring well completed at Borehole 3 at the Mill Building was used as an indication of background conditions. This well was completed in till and is considered to be free of contaminants. Note that soil sample BH3-2 from this same borehole was also used to establish soil background conditions for this site.

TABLE 5.4

GUIDELINES FOR DRINKING WATER QUALITY

Parameter	Maximum Acceptable Concentration (mg/L)
Arsenic	0.05
Cadmium	0.005
Chromium	0.05
Copper	1.0
Lead	0.05
Zinc	5.0
Phenols	0.002
Chloride	250
Nitrate (N)[1]	10.0
Sulfate	500
pH[2]	6.5 - 8.5

[1]Where both nitrate and nitrite are present the total nitrate plus nitrite (as nitrogen) should not exceed 10 mg/L.

[2]Logarithmic scale, no units.

6 - NATURE AND EXTENT OF CONTAMINATION

Before describing the extent of contamination at each site, an overview of the nature of contamination is provided. This is discussed in terms of the results given by each chemical group and its adequacy as an indicator of contamination.

Oil and grease (Group 1) in soils was found to be the most useful indicator of organic contamination and correlated well with the physical signs of contamination observed in the field (oil stains, floating product on the water surface and oily or solvent-type odors). High concentrations were detected at all three sites, but particularly at the Mill Building where oil and grease exceeded the soil removal criteria.

Under the Group 2 parameters, phenolics were not found to be a very useful indicator of organic contamination. At all three sites phenolics were below the soil cleanup criteria whereas in water all but one sample was equal to or exceeded drinking water standards. In general, phenolics did not correlate well with the trends exhibited by oil and grease. Both oil and grease and heavy metals were found to be more consistent indicators of contamination arising from petroleum refining activity. At the concentrations measured at the sites, phenolics could be a result of overall low-level contamination but they could also be a natural product of decay in organic matter.

High concentrations of heavy metals were detected at the three sites. They are the main type of contamination in both the soil and groundwater at the Waste Disposal site and were found to be associated with organic contamination of the soil at the Mill Building. In some soil locations nickel and/or zinc exceeded the cleanup criteria at both the Waste Disposal site and the Mill Building while these and several other heavy metals (cadmium, chromium, copper, lead and vanadium) were substantially higher than background conditions at all three sites.

Contamination of groundwater by heavy metals was only found in one area at the Waste Disposal site. In all other areas, arsenic, copper and zinc were below drinking water standards while cadmium, chromium and lead were below detection limits. Note, however, that the detection limits for these latter metals are higher than the drinking water criteria.

With the exception of PAHs at the Mill Building, the Group 3 organic compounds were not detected in the soil. Halogenated aliphatic compounds, chlorobenzenes, PCBs and ethanolamines were all below the detection limits in the soil. Furthermore, with one exception, there was no indication of overall degradation of surface waters or groundwater as given by the major ions under this group. The major ions were found to below drinking water standards. In comparison to background conditions, none of the three major anions which may have been inorganic indicators of contamination (sulfate, nitrate and chloride) suggested any significant anomalies. No differences existed that could not be attributed to the nature of the soil type in which the wells were completed. The one exception noted above was sulfate at Borehole 3 at the Tank Farm. This may reflect the presence of construction waste.

The major ions did indicate that the majority of the waters were of a calcium-bicarbonate type water and near neutral pH. The exceptions to this were groundwater in Boreholes 1 and 2 at the Tank Farm, the surface and groundwater north of the warehouse at the Mill Building and surface water in the trench at the Waste Disposal site. These were a calcium and a mixture of bicarbonate and sulfate type waters. The only significantly different water was from the groundwater in the peat deposit at the Tank Farm. This was more acidic and higher in sodium and chloride ions. Specific conductance was within the range expected for surface waters and groundwaters, but did indicate some localized regions of higher salinity.

6.1 - Tank Farm

The chemical analysis of soil and groundwater samples indicates that this site is not excessively contaminated. Apart from the area surrounding Testpit 2, the soils are generally acceptable while all of the groundwater constituents, except phenol, are below drinking water criteria. Table 6.1 summarizes the pertinent data for this site. The complete set of data is provided in Appendix F and G.

Although none of the constituents in soils exceeded the removal criteria, both oil and grease and vanadium from a surface sample near Testpit 2 are very close to the recommended guideline. An elevated concentration of nickel was also found in the soil sample obtained from this testpit. The oil and grease and vanadium results, together with the observation of a film of floating oil product on the water seeping into Testpit 2, suggests that crude oil is the likely source of these contaminants. This may possibly be a result of former fire drill activities carried out on the site.

Only one other area of the site indicated an elevated concentration of oil and grease. This was from a near-surface sample of peat at Borehole 4 which, although substantially higher than background conditions, was below removal criteria. The results from Borehole 2 typify the general trend for oil and grease to decrease in concentration with depth. This suggests that organic contamination is limited to the upper part of the fill.

As can be seen from Table 6.1, phenolics in the soils do not correlate with the oil and grease results. Phenolics remain virtually unchanged despite changes in the concentration of oil and grease by several orders of magnitude. In groundwater, the concentration of phenolics exceeded the drinking water standards in all 4 boreholes on this site. However, phenolics in all of the soil samples from this site were well below the soil removal criteria, and in fact were below the results for

TABLE 6.1

SELECTED SAMPLES - TANK FARM SITE

Sample Location	Sample No.	Soil			
		Oil and Grease (ug/g)	Phenolics (ug/g)	Ni (ug/g)	V (ug/g)
TP2	-1			87.6	
SS (near TP2)		19 688	0.14		241
BH2	-1	674	0.17		
	-2	198	0.13		
	-3	138	0.085		
	-4	83	0.13		
BH4	-2	6 814	0.14		
BK1 (south of road)		60	0.54	1.7	2.3
BK2 (new waste site)		92	0.31	1.8	4.0
Criterion		20 000	10	200	250

Sample Location	Water
	Phenolics (mg/L)
BH1	0.009
BH2	0.012
BH3	0.024
BH4	0.038
Criteria	0.002

BH - Borehole
TP - Testpit
SS - Surface sample
BK - Background
__ - in excess of criteria

phenolics in the two background soil samples. This indicates that phenolics are naturally present in the soil. The high concentration of phenolics in groundwater is likely to be a result of their presence in the soil and high solubility. In regards to heavy metals, the water chemistry results indicated that they are not leaching into the groundwater to any significant degree.

6.2 - Mill Building

The chemical test results from the soil samples confirmed the physical signs of contamination which were observed at this site. The oil-stained area and the oily or solvent-type odors detected in the shallow surface layer in the general vicinity of the fenced compound corresponded to excessive concentrations of oil and grease. Elevated concentrations of heavy metals and some PAHs were also found in the soils in this area.

Table 6.2 summarizes some of the relevant sample data for this site. Included in this table are some phenolic and heavy metal results which were considerably higher than soil background conditions. Those constituents which exceeded the soil removal criteria are underlined. The complete data set is provided in Appendix F and G.

Oil and grease concentrations exceeded the removal criteria (2%) within the top 5 to 20 cm of the soil surface at Auger holes 1, 4 and 5. The maximum oil and grease concentration was 3.9% from the upper 5 cm of the oil-stained soil at Auger hole 5. This soil layer also contained the highest concentration of phenolics out of the samples tested and contained elevated concentrations of several heavy metals in comparison to soil background conditions. Vanadium, in particular, was high at Auger hole 5 while nickel exceeded the removal criteria at Auger hole 4.

TABLE 6.2

SELECTED SAMPLES - MILL BUILDING SITE

Sample Location	Sample No.	Soil Oil and Grease (ug/g)	Phenolics (ug/g)	Zn (ug/g)	Pb (ug/g)	Ni (ug/g)	Cr (ug/g)	V (ug/g)
A1	-1	22 423						
	-2	28 668						
A2	-1	1 339						
	-2	5 316						
A3	-1	8 585						
	-2	3 181						
A4	-1	24 305				477		
	-2	12 498						
A5	-1	38 641	1.50	67.7	101.7		11.4	100.6
	-2	1 181			76.9			
TP2	-1	8 617						
	-2	15 579		68.7				
	-3	1 243						
	-4	175						
TP3	-1	6 046				58.4	34.2	
BH4	-2	44	0.125					
BH3 (background)	-2		0.25	5.6	3.3	3.1	1.1	<18
Criterion		20 000	10	800	1000	200	1000	250

Sample Location	Water Oil and Grease (mg/L)	Phenolics (mg/L)
BH1		0.002
BH2	5.6	0.019
BH4	27.7	0.070
	17.3*	0.030
BH3 (background)	2.8	0.002
Criteria		0.002

A - Auger hole
BH - Bore hole
TP - Testpit
* - Resampled at a later date
___ - In excess of criteria

Although they did not exceed the removal criteria, the oil and grease concentrations in the shallow soil from Testpit 2 and Auger holes 2 and 3 were also high. Several of the lower molecular weight PAHs were also detected in this soil at Testpit 2 and Auger hole 5 (see Appendix F.4), although their concentrations were below the cleanup criteria.

In groundwater, the oil and grease concentration was considerably higher than background conditions at Borehole 4, while phenolics in this borehole and Borehole 2 were higher than the drinking water standard. As soil sample BH4-2 had relatively low concentrations of both these parameters and was in a saturated state, the organics detected in the groundwater at Borehole 4 are considered to exist as a surface film rather than in solution. A diesel or solvent type smell was noted in the soil from Borehole 4. As the concentration of oil and grease in Borehole 2 is not overly high, the phenolics at this borehole are considered to be natural in origin.

The only parameters which were substantially higher than soil background conditions outside of the fenced compound area were elevated concentrations of oil and grease, nickel and, to a lesser extent, chromium from the surface layer at Testpit 3. This testpit is adjacent to one of the stockpiled drums. These constituents, however, did not exceed the removal criteria.

6.3 - Waste Disposal Site

The analysis of the soil and water samples collected from this site indicates that there is overall low-level contamination of the site by some heavy metals, particularly in the general area of the leachate springs. Table 6.3 is a summary of the relevant chemical data discussed in this section. In general, this table highlights the chemical parameters in soil which either exceeded the removal criteria or were measured at concentrations substantially in excess of background conditions. It also presents those groundwater constituents

TABLE 6.3

SELECTED SAMPLES - WASTE DISPOSAL SITE

Sample Location	Sample No.	Soil Oil and Grease (ug/g)	Phenolics (ug/g)	Zn (ug/g)	Pb (ug/g)	Cu (ug/g)	Ni (ug/g)	Cr (ug/g)	Cd (ug/g)
TP4	-1			27.5	39.7	62.7			
TP5	-2	3 462							
	-3	5 426		36.1					
BH2	-3		0.51	27.1	13.9				
BH3	-1		0.94	139.8	18.3		13.7		
LS1				1 540		57.6	290		7.8
LS2				33.5					
LS3				31.5			62.3	61.9	
LS5				15.0		18.0			
LS6 dup				13.3					
BK		39	<0.05	0.74	0.6	1.7	<1	0.9	<.3
Criterion		20 000	10	800	1000	300	200	1000	8

Sample Location	Water Phenolics (mg/L)	Zn (mg/L)	Cu (mg/L)	Ni (mg/L)	Cr (mg/L)	Cd (mg/g)
BH1	0.006					
BH2	0.005					
BH4	0.015					
BH7	0.005					
LS5		21.6	5.4	6.4	1.2	0.06
LS6 dup		5.9		1.5		
Trench	0.006					
Bog (near BH7)	0.006					
Criterion 0.002		5.0	1.0		0.05	0.005

TP - Testpit
BH - Borehole
LS - Leachate Spring
BK - Background
__ - In excess of criteria

which were found to be higher than the drinking water criteria. Appendix F and G provide the entire data set.

In the case of heavy metals, most were found to exceed the soil background condition for this site. This may imply that the metal concentrations in the background soil sample may be much lower than typical conditions. Nevertheless, of these constituents, zinc would appear to be a good indicator of heavy metal contamination at this site. As can be seen from Table 6.3, other heavy metals accompany the trend shown by increasing concentrations of zinc. This is similarly reflected in the water analyses.

The chemical data for both soils and water indicate that the areas around the leachate springs are the most contaminated. In particular, soil sample LS1 was in excess of the removal criteria for both nickel and zinc, while at least one of two leachate groundwater samples had concentrations of cadmium, chromium, copper and zinc above the drinking water standards. Elevated concentrations of nickel were also found in both of these groundwater samples. The source of these metals in the soil may be due to a slow accumulation of metals precipitating out of the leachate. Although the concentration of heavy metals in soil was not overly high at Borehole 4 (adjacent to the leachate springs), this is not to imply a source does not exist. In fact, Testpit 4 and, to a lesser extent, Borehole 2 and Testpit 5 which are located on the crown of the site, indicate low-level heavy metal contamination of the soil.

In other areas of the site, elevated concentrations of some heavy metals were found from a soil sample at Borehole 3 while nickel was higher than the drinking water standard in the trench water. Nickel in this water may be a reflection of mill scale that has been periodically dumped into this trench.

The concentration of nickel in the trench water and heavy metal contamination in the area of the leachate springs indicate that these contaminants at the Waste Disposal site can migrate off-site.

In regards to organic contamination, neither oil and grease nor phenolics were measured at concentrations above the removal criteria in any of the soil samples. Some of the soil samples from the unvegetated area at Borehole 4 and Testpit 5 showed elevated oil and grease values. This suggests that organic contamination at the Waste Disposal site may be limited to this area. Although phenolics in groundwater were consistently measured at or above the drinking water standard, these concentrations are not considered to be of concern.

7 - RECOMMENDED REMEDIAL MEASURES

Remedial cleanup options applicable to this study fall into three broad categories.

1 - No corrective action.

2 - Control the source of the contaminants and allow natural processes to remove any contaminants from the groundwater.

3 - Control the source of the contaminants and recover the contaminants from the groundwater for treatment purposes.

A breakdown of the commonly implemented techniques within the latter two categories is presented in Table 7.1. The choice of which technique is appropriate for a particular site is contingent on a good understanding of its hydrogeologic setting and the nature of the contaminant(s). Inherent in the selection of the preferred technique are evaluations of both the contaminant threat to the public and/or environment and of the feasibility of the scheme in terms of its cost and proposed effect on reducing or eliminating that threat.

Of the two options listed in Table 7.1, groundwater rehabilitation (Category 3) and incinerating or fixating wastes under Category 2, were not considered suitable for the following reasons.

(i) Groundwater rehabilitation: This category was dismissed because none of the three sites has groundwater contamination sufficient to warrant collection and treatment. Groundwater treatment is generally required as a supplement to source control only when the concentration of contaminants is such that it immediately threatens a water supply or a marine aquatic environment. A water supply does not exist at present anywhere within the influence of the three sites and their locations are

TABLE 7.1

REMEDIAL CLEANUP OPTIONS

Category	Specific Technique	Available Methods	Advantages	Disadvantages
1 - no corrective action	n/a	n/a	no cost	- continuation of leachate generation, and possible source aggravation by disposal of additional wastes
2 - control the source without groundwater rehabilitation	(a) incineration	n/a	- removes waste and destroys or reduces waste volume - no further leachate generated	- expensive, waste specific and requires implementation of option 2(a) for existing source
	(b) fixation	lime, cement, polymers	- reduces amount and concentration of leachate generated by immobilizing particular waste	- expensive, waste specific and requires implementation of option 2 (a) for existing source
	(c) excavation	n/a	- removes waste to secure site - no further leachate generated	- possibly expensive depending on waste volume
	(d) containment	- cut-off wall - capping - interceptor/ collector trench-drains - well system	- reduces amount and concentration of leachate generated by minimizing contact with waste	- possibly expensive, depending on method(s) used and site properties
3 - control the source with groundwater rehabilitation	As above plus chemical/ biological wastewater treatment	Numerous waste specific methods	- reduces leachate concentrations to acceptable criteria	- expensive due to high operation and maintenance costs, and waste specific

sufficiently far removed from Placentia Bay to permit sufficient mixing of all groundwater discharges with surface water runoff.

Typically, this approach is appropriate with dealing with an extensive area of contamination. This is not the case for any of the three sites. Furthermore, groundwater rehabilitation itself is not appropriate without some form of source control. Therefore with some reduction or elimination of the source of contaminants in the immediate future, no groundwater treatment is deemed necessary.

(ii) Incinerating or fixating wastes: These options were considered and rejected, because both require excavation of the source of the waste and are waste specific in terms of their processing requirements. In general, excavation and haulage of a waste from an existing site to a nearby secure site is less costly than either of the above mentioned options. With respect to the processing requirements, all three sites contain a variable mixture of waste materials and therefore it is considered impractical to either separate the waste for incineration or select a binding agent suitable for fixating all of the wastes present. Furthermore, even if incineration was economically feasible there are no incinerators close to the refinery suitable for industrial waste.

Having eliminated the above options on the basis of both economics and technical requirements the remaining options include category 1 (no corrective action) and excavation/reburial and containment under category 2. Based on the field investigation and chemical test results, these three options were compared for each site. The particular option recommended and the reasons for its selection are outlined for each site as follows.

7.1 - Tank Farm

As previously noted in Sections 4.1 and 6.1, the main area of concern is the more permeable fill materials lying along the north and east margins of the site. A considerable amount of construction waste was noted at Testpit 2 and some of the contaminant concentrations in the surface soil were close to removal criteria. Oil-stained sand layers were also encountered at Boreholes 2 and 3, with the former borehole also situated adjacent to drums of stored waste oil which were observed to have leaked. Despite the borderline soil conditions, the quality of the groundwater obtained from both the fill and underlying peat generally falls within acceptable criteria.

Since this site does not appear to be highly contaminated, the no corrective action approach was considered. However, although soil conditions were generally found to be acceptable, the refractory brick and excavated fill from the crude pumping station effectively covered most of the site. They therefore made a thorough assessment of the extent of any contamination, including visual identification of critical areas, difficult. Even though the DOE reports that most of the refractory brick has now been removed, the area is still covered by the fill from the crude pumping station. In essence, although its hydrogeologic setting is reasonably well understood, there is sufficient field evidence to indicate that contaminants could have gone undetected at the level of the investigation used for this study.

It is therefore recommended that a decision on a remedial course of action be deferred pending some additional evaluation of the site. Further testpitting and a limited amount of chemical testing (oil and grease and selected metals) are suggested as a cost-effective means of more closely examining the fill materials. It is anticipated that the results of this program will either support the no corrective action approach or demonstrate a need for removal of some contaminated fill to a more secure site. Containment is not considered a viable option as the site is not immediately underlain by an impermeable base. Any

efforts made to seal the site without this base would likely have either limited success, or may prove prohibitive in cost in order to reach an adequate base.

Unless this additional investigation indicates other areas of contamination require removal, only the oil-stained areas in the adjacent peat need to be removed from the site.

7.2 - Mill Building

The high oil and grease results and elevated values of heavy metals and PAHs found in the surface layer of soil in the general vicinity of the warehouse and office building indicates that contamination appears to be limited to the top 0.3 m of soil. This area consists of the oil-stained area, the fenced compound and the surrounding area containing construction debris. Note that these areas do not necessarily correspond to visible signs of contamination.

Since the soil contamination in this area exceeds removal criteria it is recommended that the contaminated layer (see Figure 7.1) be excavated and removed to a secure site. This course of action is appropriate considering the area is, and will likely continue to be, actively used. Containment is not viable as the volume of contaminated soil is relatively small (about 600 $m^{3)}$, and is spread over a wide area (0.2 ha).

After the soil has been removed to the waste disposal site, further sampling and testing should be carried out to confirm that the objectives of the cleanup program have been met.

There does not appear to be a similar need to remove the surface layer from the area surrounding the stockpiled drums. The testpits excavated in this area supported the supposition that drums were not buried at this location. Furthermore, all of the soil chemistry results

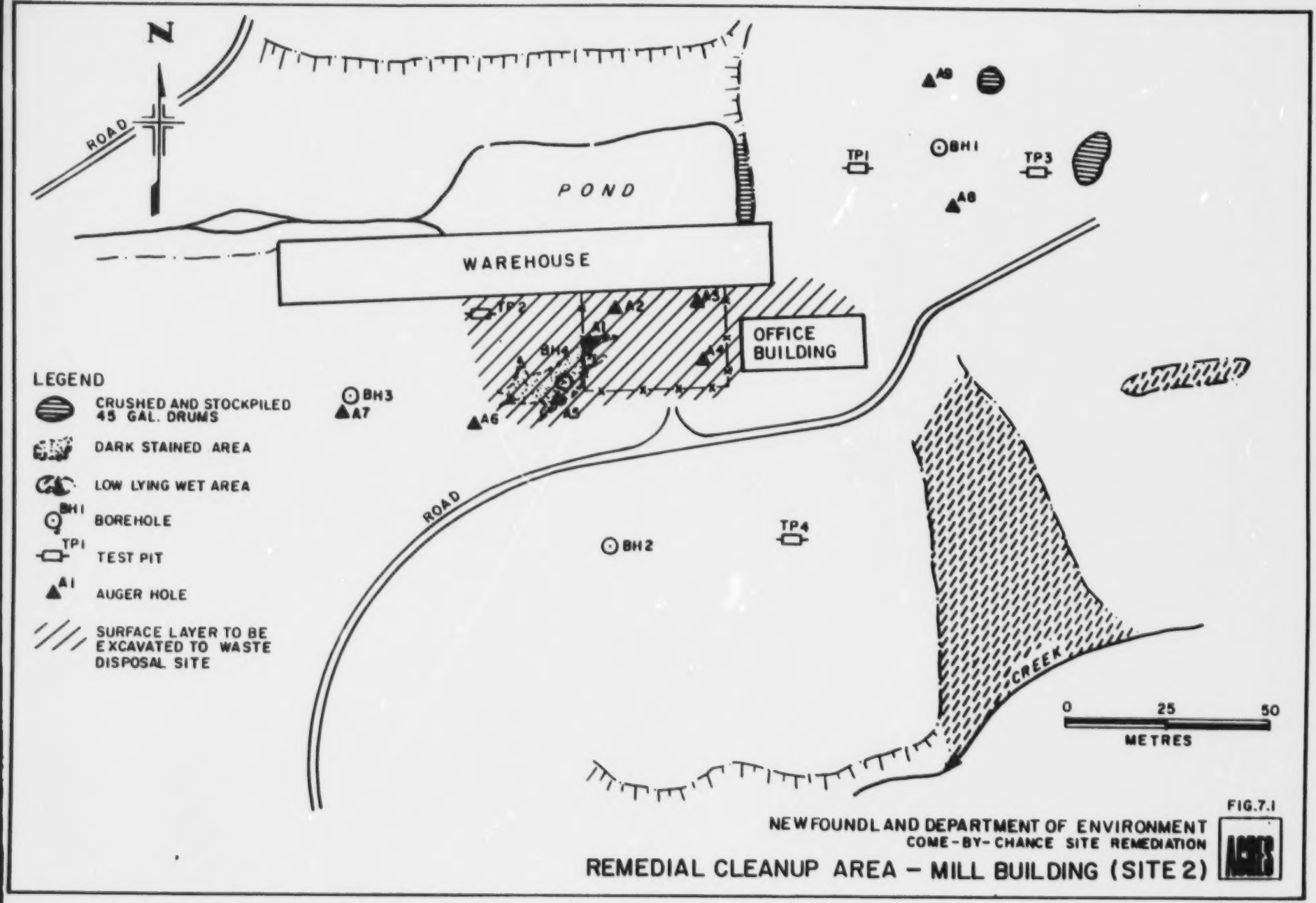


FIG.7.1

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

REMEDIAL CLEANUP AREA – MILL BUILDING (SITE 2)

indicated concentrations below removal criteria. Therefore, only the stockpiled drums and, as a precautionary measure, the 0.1 m surface layer immediately below the drums should be removed.

Apart from elevated phenol at Borehole 4, the chemistry results indicate the groundwater is satisfactory. Removal of the source should address any concerns regarding potential groundwater contamination.

7.3 - Waste Disposal Site

This site consists of a crown of very permeable fill (largely construction waste) which, in turn, overlies a less permeable base composed of either fill or till over bedrock. Leachate springs are seeping from the sides of this fill, particularly along the western edge. The soil chemistry results from this area show elevated values of oil and grease around Borehole 4 and Testpit 5 and excessive metal concentrations in both the soil and water around the area of the leachate spring (see Section 6.3).

In the peripheral areas around the crown, the physical evidence shown by both the surface expression and the testpits indicate little waste material and therefore these areas do not require substantial cleanup. Despite the occurrence of excessive to elevated concentrations of oil and grease and metals in some soil locations, these anomalies are not reflected in the groundwater. Therefore no particular remedial measures are required to treat the groundwater.

In regards to the crown of waste material, the three remedial alternatives available for this site are a no corrective action approach, excavating and reburying the source in a secure manner or in-situ containment.

The first alternative is not recommended since excessive concentrations of contaminants were observed in the soils and, to a lesser extent, in

the groundwater. Further, the off-site flux of groundwater contaminants may be higher during a wetter period than that which occurred during this investigation. In this regard, although groundwater contamination was localized during the investigation, the summer of 1987 was abnormally dry and therefore the groundwater contamination results may be misleadingly low. Another point in favor of adopting some form of corrective action is that it may prevent future problems. If the site is left in its present state there is the possibility that additional wastes may be brought to the site or the existing materials may be disturbed. Measures would have to be implemented to regulate its use on a continual basis to prevent such problems. Finally, in the previous sections, it has been recommended that removal of contaminated soil to a secure site be carried out from the Mill Building site and possibly from the Tank Farm site at a later date. Hence, the need for a secure site exists.

The remaining options are thus limited to relocating fill from the Waste Disposal site, or controlling the source. The alternative of relocating waste from any of the three sites may have been viable if a secure site in the area were already available. Although there is a new disposal site presently being considered for the refinery southeast of the plant, a self-contained solution not utilizing this proposed facility is preferred. Therefore, it is recommended that improvements be made to the Waste Disposal site in order to both secure it and enable it to receive fill from the other two sites. This is recommended for the following reasons.

- it is the only nearby site suitable for containment.

- it is the largest of the three sites (and accordingly would be the most costly in terms of removing and relocating fill).

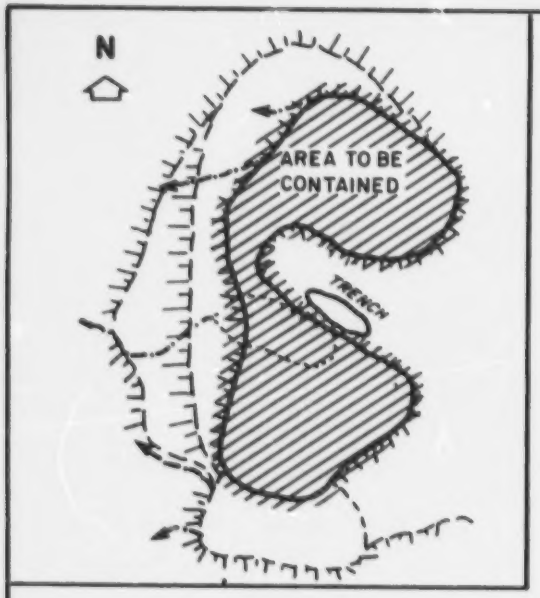
- it is the most isolated from any likely future industrial activity.

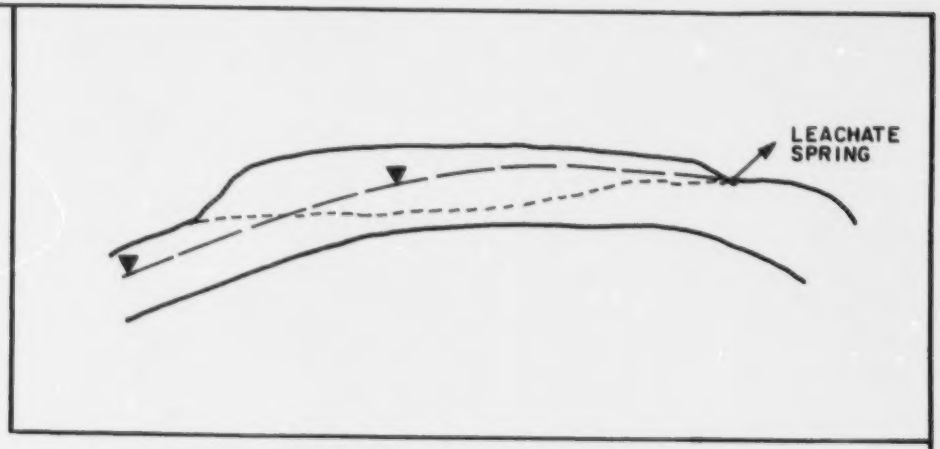
Insofar as controlling the source by containment is concerned, the most effective method is to contain the crown of the site by capping it with a cover and sealing the perimeter with a trench cut-off wall. A properly designed cover will not only reduce the amount of precipitation infiltrating into the crown but will also promote better surface runoff through ε suitably graded slope. The end result will be a reduction in the amount of seepage flowing off the site. To maintain a lower internal water table (thus reducing the water in contact with the fill materials) and to direct the small amount of residual leachate generated to a suitable collection point, a collector drain will be required around the inside base of the perimeter trench cut-off. As site seepage cannot be totally eliminated, long-term monitoring will be required. In this regard the collector drain will permit ready sampling of any leachate generated. At this time it is suggested that the materials used for the cover and cut-off wall be constructed out of locally available native soils. Suitable materials are expected to be available within a 3-km radius. Any fill removed from the other sites should be placed at the Waste Disposal site before capping.

Some of the design details concerning the components of the cover and cutoff scheme are illustrated in cross section in Figure 7.2 and are described as follows.

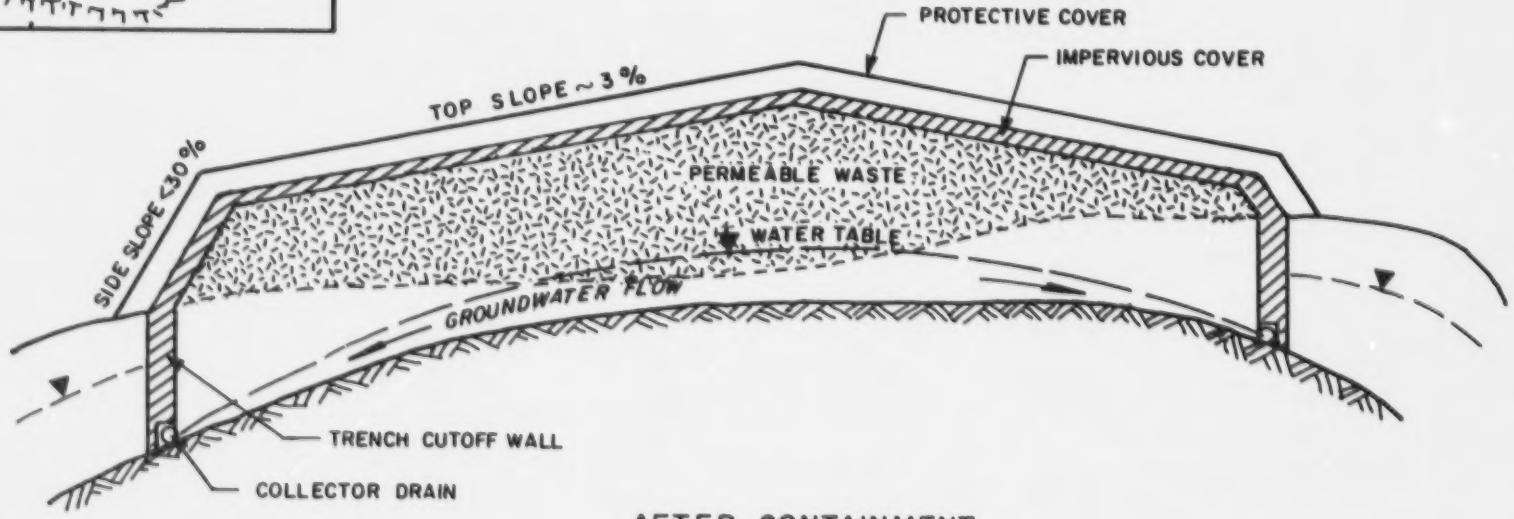
- The containment scheme comprises two covers--an impervious cover to limit infiltrating waters to the site and an overlying protective cover to maintain the integrity of the impervious cover.

- The impervious cover consists of at least a 0.5 m thick layer of suitably fine-grained impermeable materials compacted to minimum of 95% of Standard Proctor density; the hydraulic conductivity should be less than 10^{-7} cm/s after compaction and will therefore need to contain at least 5% clay content.





BEFORE CONTAINMENT



AFTER CONTAINMENT

NOT TO SCALE

FIG. 7.2

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

CONCEPTUAL CROSS SECTION OF CONTAINMENT SCHEME

- In order to promote surface runoff (limit infiltration) and yet still minimize surface erosion, the slope of the main body of the cover should be about 5% with side slopes not to exceed 30%. This requirement will involve some regrading of the site before placing the cover. Special care, possibly including hydroseeding, will be required to ensure rapid stabilization of the side slopes.

- The impervious cover should to be keyed into a relatively impermeable base around the perimeter of the crown; a trench cutoff should therefore be excavated to till or bedrock and the cover continued into the trench with the same impermeable materials.

- Before backfilling and compacting the trench cutoff, a perimeter tile drain surrounded by washed aggregate should be placed around the inside base of the trench in order to collect any leachate generated and route it to a suitable collection point.

- Upon construction of the impervious cover and cutoff wall, a protective cover at least 1 m thick should be placed over the top and stabilized with vegetation; the purpose of this cover is to protect the underlying impervious cover from freeze/thaw action and to prevent disruption by vegetation roots. This cover should consist of a silty or clayey-sand.

- A further requirement which may be incorporated is the installation of gas vents to prevent the build-up of gas beneath the impervious cover. This should be assessed as part of the final design.

7.4 - Groundwater Monitoring

Currently there are no existing monitoring wells which could be used for the purposes of providing overall background water quality conditions. It is therefore recommended that at least one well be installed outside of the three site drainage areas. It is suggested

that a shallow well be installed in glacial till due east of the refinery which, for convenience, could be situated in an isolated area near the intersection of the main refinery road and the access road to the refinery's proposed new landfill.

To assess the effectiveness of the remedial measures previously recommended, it will be necessary to implement a groundwater monitoring program. At this time it is suggested that all monitoring wells, including the well recommended for background comparisons, be initially monitored for water levels on a quarterly basis. Water samples should be collected from the wells on a semi-annual basis and analyzed for the parameters listed below. Based on the results of this program the appropriateness of the sampling period and testing can be reviewed on a yearly basis.

Site	Borehole No.	Chemical Analysis
Tank Farm	2	oil and grease
Mill Building	4	oil and grease
Waste Disposal	3, 4, 6	oil and grease, selected heavy metals
background		oil and grease, phenolics, heavy metals, major ions and general parameters.

The basis on which the above wells were selected is outlined below. The particular chemical parameters recommended for analysis are the parameters which are of concern at each site.

Borehole 2 at the Tank Farm site is situated in the more permeable materials at this site and along the groundwater flow path discharging to the northwest. It is therefore representative of groundwater conditions in this area. Sampling for oil and grease as a general indicator of organic contamination is only recommended at this time.

Monitoring Borehole 4 at the Mill Building site will permit monitoring of the groundwater conditions in the vicinity of the oil-stained area following removal of the surface layer. Oil and grease is the only parameter of interest that should be sampled at this site.

Borehole 4 at the Waste Disposal site is situated at the crown of the site while Boreholes 3 and 6 are located downgradient of this along the eastern and western flanks of the site, respectively. These wells will provide representative spatial coverage of groundwater conditions at the site. Oil and grease and some selected heavy metals (zinc, copper, chromium, nickel and cadmium) are the notable chemical parameters that should continue to be tested for at this site.

After the site has been contained, it will be important to collect samples of any leachate from the collector drain for the same analyses.

7.5 - Remedial Cost Estimate

A preliminary cost estimate for undertaking the recommended remedial works outlined in the previous sections is summarized in Table 7.2. The estimate includes a 20% contingency on the construction costs (partly to account for the possibility of excavating and hauling some contaminated soil from the Tank Farm) and 15% for overall engineering design and supervision. The cost estimate in 1987 dollars is $400,000. The cost includes installation of the new background well plus setting up the first year monitoring program.

TABLE 7.2

REMEDIAL COST ESTIMATES

Item	Area (m^2)	Average Thickness (m^3)	Perimeter (m)	Resulting Volume (m^3)	Unit Price ($)	Cost ($)
Mobilization/demobilization						10,000
Testpitting at TF and chemical testing						5,000
Excavation and haulage of contaminated soil from MB to WD	2,000	0.3		600	8	~5,000
Regrading disturbed site at MB with clean soil	2,000	0.3		600	8	~5,000
Haulage, spreading and compaction of suitable material for impervious cover at WD	9,000	0.5		4,500	12	54,000
Trenching, haulage, spreading and compaction of suitable material for perimeter cut-off trench at WD	5		500	2,500	27	~68,000
Placement of collector drain and wash aggregate at WD			500		20	10,000
Haulage and spreading of material for protective cover	10,000	1.0		10,000	8	80,000
Vegetation of protective cover	10,000				5	50,000
						287,000
				Contingency (20%)		58,000
						345,000
				Engineering (15%)		52,000
First Year Monitoring at TF, MB and WD and installation of background well						3,000
						~400,000

TF - Tank Farm
MB - Mill Building
WD - Waste Disposal

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APPENDIX A

AUGERING REPORTS
TEST PIT REPORTS

Drilling Report

JOB P8143.00
HOLE MB-A1
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

STARTED 1000 May 12, 1987

METHOD OF
DRILLING : Soil Hand Augering

FINISHED 1020 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.5 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE #TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Light brownish gray sandy gravel, moist, faint oily odor	BQ	1	bulk	0.0 - 0.05
0.05	Sandy gravel (fill)	Light gray sandy gravel, moist	BQ	2	bulk	0.05 - 0.19
0.19		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-A2
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

STARTED 1030 May 12, 1987

METHOD OF DRILLING : Soil Hand Augering

FINISHED 1050 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.8 m (approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravel (fill)	Fine gravel, some sulphur fragments	BQ	1	bulk	0.0 - 0.05
0.01	Silty sand (fill)	Light reddish brown silty sand, some fine gravel, moist				
0.03	Sandy gravel (fill)	Light gray sandy gravel, moist, oily odor	BQ	2	bulk	0.05 - 0.19
0.19		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-A3
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

STARTED 1100 May 12, 1987

METHOD OF
DRILLING : Soil Hand Augering

FINISHED 1120 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.8 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Light gray sandy gravel, moist, faint oily odor	BQ	1	bulk	0.0 - 0.05
0.05	Sandy gravel (fill)	Dark reddish brown sandy gravel, trace clay	BQ	2	bulk	0.05 - 0.23
0.11	Silty sand (fill)	Light grayish brown silty coarse sand, trace clay, moist				
0.23		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – open barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Drilling Report

JOB P8143.00
HOLE MB-A4
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

STARTED 1130 May 12, 1987

METHOD OF
DRILLING : Soil Hand Augering

FINISHED 1150 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.4 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravel (fill)	Fine gravel	BQ	1	bulk	0.0 - 0.05
0.01	Gravel (fill)	Dark reddish brown fine gravel, trace clay, moist, faint solvent type odor				
0.03	Silty sand (fill)	Light grayish brown silty coarse sand, moist to wet with depth	BQ	2	bulk	0.05 - 0.22
0.22		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-A5
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

LOCATION : See Figure 2.3

METHOD OF
DRILLING : Soil Hand Augering

SITE Mill Building (Site 2)

STARTED 1200 May 12, 1987

FINISHED 1220 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.4 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Dark brown sandy gravel gravel, wet, organic odor	BQ	1	bulk	0.0 - 0.05
0.04	Gravel (fill)	Dark reddish brown fine angular gravel, some fine sand, wet	BQ	2	bulk	0.05 - 0.14
0.14		Bottom of auger hole				

Notes

2 cm of water in hole by end of augering.

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – open barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-A6
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

STARTED 1350 May 12, 1987

METHOD OF
DRILLING : Soil Hand Augering

FINISHED 1400 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.4 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Organic	peat, wet	BQ	1	bulk	0.0 - 0.06
0.01	Sandy gravel (fill)	Sandy angular gravel, wet, stained light red				
0.06	Sandy gravel (fill)	Light brown sandy angular gravel, some silt, wet	BQ	2	bulk	0.06 - 0.22
0.22		Bottom of auger hole				

Notes

22 cm of water in hole by end of augering.

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318.A (1)

Drilling Report

JOB P8143.00
HOLE MB-A7
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

LOCATION : See Figure 2.3

METHOD OF
DRILLING : Soil Hand Augering

SITE Mill Building (Site 2)

STARTED 1410 May 12, 1987

FINISHED 1415 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.3 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravel (fill)	Angular fine gravel	BQ	1	bulk	0.0 - 0.05
0.07	Sandy gravel (fill)	Light reddish brown sandy gravel, moist, faint organic odor	BQ	2	bulk	0.05 - 0.17
0.12	Sandy gravel (fill)	Light gray sandy gravel, wet				
0.17		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-A8
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

STARTED 1420 May 12, 1987

METHOD OF
DRILLING : Soil Hand Augering

FINISHED 1430 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.5 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravelly sand	Light orangish brown gravelly coarse sand, moist (till)	EQ	1	bulk	0.0 - 0.05
0.05	Gravelly silt	Light gray gravelly silt, trace clay, moist, (till)	EQ	2	bulk	0.05 - 0.14
0.14		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-A9
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

LOCATION : See Figure 2.3

METHOD OF
DRILLING : Soil Hand Augering

SITE Mill Building (Site 2)

STARTED 1440 May 12, 1987

FINISHED 1445 May 12, 1987

ELEVATIONS: Datum BH-1, 100 m
Ground Surface 99.4 m
(approx.)

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravelly silt	Dark brown gravelly silt, trace clay, dry (till)	BQ	1	bulk	0.0 - 0.20
0.20		Bottom of auger hole				

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Test Pit Report

JOB P8143.00
PIT TF-TP1
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Tank Farm (Site 1)

LOCATION : See Figure 2.2

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 12:15 May 26, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 12:40 May 26, 1987

WEATHER Sunny, clear — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 103.5 m — BOTTOM OF PIT 100.0 m

GROUND SURFACE 101.5 m — WATER LEVEL See App. C

ROCK SURFACE n/a

PIT LENGTH 2.0 m — WIDTH 1.0 m — DEPTH 1.5 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravelly sand (fill)	Dark brown gravelly fine sand, some silt, occasional boulders, compact to dense, dry 1.05 - 1.1: some wire, nails and roots	GQ	1	bulk	0.0 - 1.1
1.1	Gravelly sand	Dark brown gravelly fine sand, some silt and boulders, very dense, dry (till)	GQ	2	bulk	1.1 - 1.5
1.5		Bottom of test pit				

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Test Pit Report

JOB P8143.00
PIT TF-TP2
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Tank Farm (Site 1)

LOCATION : See Figure 2.2

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 12:45 May 26, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 13:20 May 26, 1987

WEATHER Sunny, clear TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 103.5 m BOTTOM OF PIT 98.3 m

GROUND SURFACE 100.0 m WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.0 m WIDTH 1.0 m DEPTH 1.7 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Debris, refuse and sand (fill)	Mixture of wood fragments, rope, plastic hose, plastic banding, steel pipe, domestic refuse and occasional crushed 10 gal drums in gravelly, medium sand matrix, very loose, moist becoming wet with depth	GQ	1	bulk	0.0 - 1.3
1.7		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing - Nominal diameter 3.8 cm
- Height 1.4 m above ground surface
- Total length 3.1 m
- Intake interval 0.7 - 1.7 m below ground surface

2 - Water very quickly entering pit from sidewalls; 40 cm of water in testpit by end of excavation with dark floating product on water surface.

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B. G. Bennett DATE November 1987

Test Pit Report

JOB P8143.00
PIT TF-TP3
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Tank Farm (Site 1)

LOCATION : See Figure 2.2

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 13:30 May 26, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 14:00 May 26, 1987

WEATHER Sunny, clear — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 103.5 m — BOTTOM OF PIT 99.3 m

GROUND SURFACE 101.9 m — WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.3 m WIDTH 1.0 m DEPTH 2.6 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravelly sand (fill)	Dark grayish brown gravelly fine sand, some silt, compact, moist	GQ	1	bulk	0.0 - 1.0
			GQ	2	bulk	1.0 - 2.6
		0.0 - 0.1: some steel strapping				
2.6		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing - Nominal diameter 3.8 cm
- Height 1.1 m above ground surface
- Total length 3.7 m
- Intake interval 1.6 - 2.6 m below ground surface

2 - Fill consists of excavated material from new crude pumping station (Goobie Rentals & Contracting Ltd. - personnal communication).

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT MB-TP1
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 15:15 May 13, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 15:30 May 13, 1987

WEATHER Sunny TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m BOTTOM OF PIT 98.0 m

GROUND SURFACE 99.4 m WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.0 m WIDTH 1.0 m DEPTH 1.4 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel	Light brown sandy gravel, some silt, occasional boulders, very dense, dry (till)				
1.4		Bottom of test pit				

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B. G. Bennett DATE November 1987

Test Pit Report

JOB P8143.00
PIT MB-TP2
SHEET 1 OF 2

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 08:15 May 24, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 09:05 May 24, 1987

WEATHER Sunny, clear TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m BOTTOM OF PIT 97.2 m

GROUND SURFACE 99.1 m WATER LEVEL See Appendix C

ROCK SURFACE 97.2 m

PIT LENGTH 2.3 m WIDTH 1.0 m DEPTH 1.9 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Light gray sandy gravel, some concrete rubble and wood fragments, loose, wet	GQ	1	bulk	0.0 - 0.4
0.3	Sandy gravel (fill)	Light reddish brown sandy gravel, loose, wet	GQ	2	bulk	0.3 - 0.4
0.4	Sandy gravel	Light gray sandy gravel, some silt, occasionnl boulders, dense becoming very dense with depth, moist (till)	GQ	3	bulk	0.4 - 1.0
			GQ	4	bulk	1.0 - 1.9
1.9	Bedrock	Light greenish grey siltstone				
1.9		Bottom of test pit				

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B. G. Bennett DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT MB-TP2
SHEET 2 OF 2

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	1.2 m above ground surface
	- Total length	3.1 m
	- Intake interval	0.9 - 1.9 m below ground surface

2 - Water entering pit from base of surface layer (0 - 0.4 m) and base of pit at contact with bedrock.

Test Pit Report

JOB P8143.00
PIT MB-TP3
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 09:15 May 24, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 09:50 May 24, 1987

WEATHER Sunny, clear — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m — BOTTOM OF PIT 97.5 m

GROUND SURFACE 99.7 m — WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.3 m — WIDTH 1.0 m — DEPTH 2.2 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Gravelly sand (fill)	Light orangish brown gravelly coarse sand, some silt, loose, moist	GQ	1	bulk	0.0 - 0.2
0.2	Sandy silt	Light gray sandy silt, some coarse gravel, occasional boulders, dense, moist, fissured (till)	GQ	2	bulk	0.2 - 1.3
1.3	Sandy silt	Light gray sandy silt, some coarse gravel, occasional boulders, very dense, moist becoming dry with depth (till)	GQ	3	bulk	1.3 - 2.2
2.2		Bottom of test pit				

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT MB-TP4
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Mill Building (Site 2)

LOCATION : See Figure 2.3

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 10:00 May 24, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 10:45 May 24, 1987

WEATHER Sunny, clear — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m — BOTTOM OF PIT 96.3 m

GROUND SURFACE 98.9 m — WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.3 m — WIDTH 1.0 m — DEPTH 2.6 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sand and gravel (fill)	Light brown sand and gravel, subangular, loose, wet	GQ	1	bulk	0.0 - 1.1
1.1	Gravelly sand	Light grayish brown gravelly medium sand, some silt, moist and dense becoming dry and very dense with depth (till)	GQ	2	bulk	1.1 - 2.6
2.6		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	0.5 m above ground surface
	- Total length	3.1 m
	- Intake interval	1.6 - 2.6 m below ground surface

2 - Water very quickly entering pit from base of surface layer (0 - 1.1 m); sidewalls sloughing.

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

ACRES

Test Pit Report

JOB P8143.00
PIT WD-TP1
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 08:45 May 13, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 09:10 May 13, 1987

WEATHER Partial Overcast — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m — BOTTOM OF PIT 95.1 m

GROUND SURFACE 97.5 m — WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.3 m — WIDTH 1.0 m — DEPTH 2.4 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Light grayish brown sandy gravel, some silt, very loose, wet becoming moist with depth	GQ	1	bulk	0.0 - 2.1
0.7	Sandy gravel (fill)	Light gray sandy gravel, some silt, very loose, moist				
2.1	Organic	Dark brown peat, moist				
2.4		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing - Nominal diameter 3.8 cm
- Height 0.7 m above ground surface
- Total length 3.1 m
- Intake interval 1.4 - 2.4 m below ground surface

2 - Water entering pit from top of surface layer (0 - 0.7 m)

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT WD-TP2
SHEET 1 OF

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 09:15 May 13, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 09:25 May 13, 1987

WEATHER Partial Overcast TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m BOTTOM OF PIT 99.0 m

GROUND SURFACE 100.8 m WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.0 m WIDTH 1.0 m DEPTH 1.8 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Debris, refuse and sandy silt (fill)	Mixture of wood fragments, steel rope and strapping, wire, corrugated pipe, few 45 gal drum lids, rubber tire, 1 litre oil cans and domestic refuse in light brown sandy silt matrix, very loose, moist becoming wet with depth				
1.8		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	1.3 m above ground surface
	- Total length	3.1 m
	- Intake interval	0.8 - 1.8 m below ground surface

2 - Water very quickly entering pit from sidewalls;
50 cm of water in pit by end of excavation.

*SAMPLING METHOD	*SHIPPING CONTAINER	
B - thin wall tube	O - tube	S - plastic bag
G - trowel	P - tin	T - metal can
H - carved block	Q - glass jar	U - wooden box
	R - cloth bag	Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B. G. Bennett DATE November 1987

Form 314 A (2)

ACRES

Test Pit Report

JOB P8143.00
PIT WD-TP3
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 09:30 May 13, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 09:40 May 13, 1987

WEATHER Partial Overcast TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m BOTTOM OF PIT 98.4 m

GROUND SURFACE 100.9 m WATER LEVEL See Appendix C

ROCK SURFACE 98.4 m

PIT LENGTH 2.3 m WIDTH 1.0 m DEPTH 2.5 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Debris, refuse and sandy gravel (fill)	Mixture of wood fragments, steel strapping, wire, crushed 45 gal drum and domestic refuse in light brown sandy gravel matrix, very loose				
1.6	Sandy gravel	Light gray sandy gravel, some silt, wet (till)				
2.5	Bedrock					
2.5		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	0.6 m above ground surface
	- Total length	3.1 m
	- Intake interval	1.5 - 2.5 m below ground surface

2 - Water very quickly entering pit from base of surface layer (0 - 1.6 m); sidewalls sloughing; 80 cm of water in pit by end of excavation.

*SAMPLING METHOD	*SHIPPING CONTAINER	
B - thin wall tube	O - tube	S - plastic bag
G - trowel	P - tin	T - metal can
H - carved block	Q - glass jar	U - wooden box
	R - cloth bag	Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B. G. Bennett DATE November 1987

Test Pit Report

ACRES

JOB P8143.00
PIT WD-TP4
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 09:45 May 13, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 10:10 May 13, 1987

WEATHER Partial Overcast — TEMPERATURE Cool

ELEVATIONS: DATUM Top of Pipe BH1 - assumed 100.0 m — BOTTOM OF PIT 96.7 m

GROUND SURFACE 99.9 m — WATER LEVEL See Appendix C

ROCK SURFACE n/a

PIT LENGTH 2.3 m WIDTH 1.0 m DEPTH 3.2 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Light reddish brown sandy gravel, some silt, very loose, moist	GQ	1	bulk	0.0 - 1.5
0.8	Sandy gravel (fill)	Light grayish brown sandy gravel, some silt, occasional wood fragments and scraps of fabric, moist becoming wet with depth, strong smell of excrement				
3.2		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	0.2 m above ground surface
	- Total length	3.1 m
	- Intake interval	1.9 - 2.9 m below ground surface

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT WD-TP5
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 10:15 May 13, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 10:40 May 13, 1987

WEATHER Partial Overcast TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m BOTTOM OF PIT 98.2 m

GROUND SURFACE 100.5 m WATER LEVEL See Appendix C

ROCK SURFACE 98.2 m

PIT LENGTH 2.3 m WIDTH 1.0 m DEPTH 2.3 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Debris, refuse and sandy gravel (fill)	Mixture of wood fragments, steel strapping, wire, sheet metal and domestic refuse in light grayish brown sandy gravel, some silt, moist becoming wet with depth, strong oily smell	GQ	1	bulk	1.2 - 2.3
			GQ	2	bulk	0 - 1.2
			GQ	3	bulk	1.2 - 1.3
		1.2 - 1.3: oil stained gravel				
2.3	Bedrock					
2.3		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing - Nominal diameter 3.8 m
- Height 0.8 m above ground surface
- Total length 3.1 m
- Intake interval 1.3 - 2.3 m below ground surface

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B.G. Bennett DATE November 1987

Form 314 A (2)

Test Pit Report

ACRES

JOB P8143.00
PIT WD-TP6
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 10:45 May 13, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 11:10 May 13, 1987

WEATHER Partial Overcast — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m — BOTTOM OF PIT 90.7

GROUND SURFACE 93.8 m — WATER LEVEL See Appendix C

ROCK SURFACE 90.7 m

PIT LENGTH 2.3 m WIDTH 1.0 m DEPTH 3.1 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel (fill)	Light reddish brown sandy gravel, some silt, loose, moist	GQ	1	bulk	0.0 - 0.5
0.5	Sandy silt (fill)	Light grayish brown sandy silt, some gravel, moist becoming wet with depth	GQ	2	bulk	0.5 - 1.6
2.0	Organic	Dark brown peat				
3.1	Bedrock					
3.1		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	0.2 m above ground surface
	- Total length	3.1 m
	- Intake interval	1.9 - 2.9 m below ground surface

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT WD-TP7
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. STARTED 14:00 May 13, 1987

METHOD OF EXCAVATION CAT 225 FINISHED 14:05 May 13, 1987

WEATHER Sunny TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m BOTTOM OF PIT -

GROUND SURFACE - WATER LEVEL See Appendix C

ROCK SURFACE -

PIT LENGTH 2.0 m WIDTH 1.0 m DEPTH 1.1 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Sandy gravel	Light brown sandy gravel, some silt, moist (till)				
1.1	Bedrock					
1.1		Bottom of pit test				

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett APPROVED

LOGGED B. G. Bennett DATE November 1987

Form 314 A (2)

Test Pit Report

JOB P8143.00
PIT WD-TP8
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation — SITE Waste Disposal (Site 3)

LOCATION : See Figure 2.4

CONTRACTOR Goobie Rentals & Contracting Ltd. — STARTED 14:15 May 13, 1987

METHOD OF EXCAVATION CAT 225 — FINISHED 14:30 May 13, 1987

WEATHER Sunny — TEMPERATURE Cool

ELEVATIONS: DATUM Top of pipe BH1 - assumed 100.0 m — BOTTOM OF PIT 96.8 m

GROUND SURFACE 97.7 m — WATER LEVEL See Appendix C

ROCK SURFACE 96.8 m

PIT LENGTH 2.0 m WIDTH 1.0 m DEPTH 0.9 m

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)
0.0	Debris and sand and gravel (fill)	Mixture of wood fragments, insulation, scrap metal, refractory brick and electrical conduit in a light orangish brown sand and gravel matrix, very loose, dry (fill)				
0.9	Bedrock					
0.9		Bottom of test pit				

NOTES

1 - Monitoring Well Completion Details

Casing	- Nominal diameter	3.8 cm
	- Height	1.1 m above ground surface
	- Total length	2.1 m
	- Intake interval	0.0 - 0.9 m below ground surface

*SAMPLING METHOD
B - thin wall tube
G - trowel
H - carved block

*SHIPPING CONTAINER
O - tube
P - tin
Q - glass jar
R - cloth bag
S - plastic bag
T - metal can
U - wooden box
Z - discarded

INSPECTOR B. G. Bennett — APPROVED

LOGGED B. G. Bennett — DATE November 1987

Form 314 A (2)

Drilling Report

JOB P8143.00
HOLE TF-BH1
SHEET 1 OF 2

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Tank Farm (Site 1)
CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 14:30 May 16, 1987
FINISHED 08:45 May 17, 1987

METHOD OF DRILLING: SOIL NW driven casing; BW driven casing
ROCK n/a

CASING DIAM 89 mm O.D. to 1.22 m; 73 mm O.D. to 5.33 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.2
BEARING n/a
DIP Vertical

ELEVATIONS:
DATUM BH-1, 103.5 m
DRILLING PLATFORM n/a
GROUND SURFACE 103.11 m
ROCK SURFACE n/a
BOTTOM OF HOLE 97.32 m
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sand (fill)	Dark brown coarse sand, some clay, loose, moist	AS	1	35	0.00-0.46	23	4 4 4
		0.13 - 0.18: Light yellow clayey silt, moist						
0.2	Clayey sand (fill)	Dark brown to red clayey medium sand, some angular fine gravel, moist and dense becoming wet and loose with depth (refractory brick fill)	AS	2	35	0.76 1.22	46	10 19 24
			AS	3	35	1.52-1.98	24	16 14 10

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
APPROVED [signature]

LOGGED BY B. G. Bennett
DATE November 1987

Drilling Report

JOB P8143.00
HOLE TF-BH1
SHEET 2 OF 2

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)	RET'D (cm)	PENE-TRATION TEST
			AS	4	35	2.29-2.74	23	5 6 3
			AZ	5	35	3.05-3.51	0	1 2 2
			AZ	6	35	3.81-4.27	0	2 3 3
			AS	7	35	5.33-5.79	15	2 4 4
5.79		End of borehole						

Drilling Report

ACRES

JOB P8143.00
HOLE TF-BH2
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Tank Farm (Site 1)
CONTRACTOR Atlantic Geodrilling Ltd.

STARTED 11:00 May 17, 1987
FINISHED 13:15 May 17, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.59 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.2
BEARING n/a
DIP Vertical

ELEVATIONS:
DATUM BH-1, 103.5 m
DRILLING PLATFORM n/a
GROUND SURFACE 100.26 m
ROCK SURFACE n/a
BOTTOM OF HOLE 97.67 m
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sand (fill)	Dark brown fine sand, some subangular fine gravel	AS	1	35	0.00-0.46	23	9 11 15
0.1	Gravel (fill)	Subangular fine gravel, some medium sand, compact, wet						
0.6	Gravel (fill)	Angular fine gravel, some fine sand, trace silt, compact becoming loose with depth, wet, faint diesel smell	AS	2	35	0.76-1.22	24	10 13 11
		1.52-1.57: Black oil-stained fine sand, diesel smell	AS	3	35	1.52-1.98	18	12 3 5
			AS	4	35	2.29-2.59	10	5 4/30 cm
2.59		End of borehole						

SAMPLING METHOD
*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER
N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED BY B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE TF-BH3
SHEET 1 OF 2

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Tank Farm (Site 1)
CONTRACTOR Atlantic Geodrilling Ltd.

STARTED 13:30 May 17, 1987
FINISHED 09:45 May 18, 1987

METHOD OF DRILLING: SOIL BW driven casing
CASING DIAM 73 mm O.D. to 3.81 m

ROCK BQ double tubed core barrel
CORE DIAM 60 mm O.D. to 4.27 m

LOCATION: LATITUDE see Figure 2.2
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	BH-1. 103.5 m
DRILLING PLATFORM	n/a
GROUND SURFACE	102.04 m
ROCK SURFACE	98.23 m
BOTTOM OF HOLE	97.77 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Silt (fill)	Dark brown silt, some fine gravel, very dense, moist 0.20-0.30: Angular fine gravel	AS	1	35	0.00-0.43	28	6 20 42/43 cm
0.6	Sand (fill)	Black oil-stained medium sand, compact	AS	2	35	0.76-1.22	28	5 10 9
1.0	Silty gravel (fill)	Dark brown silty fine gravel, angular, compact, wet	AS	3	35	1.52-1.98	33	5 6 7
			AS	4	35	2.29-2.74	41	12 13 10

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED BY B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

ACRES

Drilling Report

JOB P8143.00
HOLE TF-BH3
SHEET 2 OF 2

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)	RET'D (cm)	PENE-TRATION TEST
			AS	5	35	3.05-3.51	18	6 5 5
						Depth of Run (m)	Core Rec'y	
3.81	Bedrock	Light greenish gray siltstone, fine grained, strong, thinly bedded				3.81-4.27	30	
4.27		End of borehole						

Drilling Report

ACRES

JOB P8143.00
HOLE TF-BH4
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Tank Farm (Site 1)

CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 08:00 May 22, 1987
FINISHED 09:30 May 22, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.29 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.2
BEARING n/a
DIP Vertical
OTHER DIPS

ELEVATIONS:
DATUM BH-1, 103.5 m
DRILLING PLATFORM n/a
GROUND SURFACE 100.53 m
ROCK SURFACE n/a
BOTTOM OF HOLE 98.24
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sandy silt (fill)	Dark brown sandy silt, very loose, moist	AS	1	35	0.00-0.46	10	1/30 cm 1/46 cm
		0.70-0.80: Light brown sandy fine gravel, moist	AS	2	35	0.76 1.22	27	5 16 1
0.8	Organic	Dark brown peat, moist	AS	3	35	1.52-2.13	46	1/61 cm
2.29		End of borehole						

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – open barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett

LOGGED BY B. G. Bennett

APPROVED [signature]

DATE November, 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE MB-BH1
SHEET 1 OF 2

CLIENT Government of Newfoundland and Labrador
Department of Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

CONTRACTOR: Atlantic Geodrilling Ltd. STARTED 09:15 May 14, 1987
FINISHED 10:15 May 15, 1987

METHOD OF DRILLING: SOIL BW wash bored casing — CASING DIAM 73 mm O.D. to 3.81 m

ROCK BQ double tubed core barrel — CORE DIAM 60 mm O.D. to 4.42 m

LOCATION: LATITUDE See Figure 2.3
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	BH-1, 100.0 m
DRILLING PLATFORM	n/a
GROUND SURFACE	99.45 m
ROCK SURFACE	n/a
BOTTOM OF HOLE	95.03 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sandy silt	Dark brown sandy silt, some subangular fine gravel, trace clay, very dense, dry (till)	AS	1	35	0.00-0.46	20	7 24 38
0.6	Silt	Light grayish brown silt, some medium to coarse sand and subangular fine gravel, trace clay, very dense (till)	AS	2	35	0.76-1.22	37	26 20 44
			AS	3	35	1.52 - 1.98	36	27 58 56

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett

APPROVED J. J. Bennett

LOGGED BY B. G. Bennett

DATE November 1987

AGRES

Drilling Report

JOB P8143.00
HOLE MB-BH1
SHEET 2 OF 2

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)	RET'D (cm)	PENE-TRATION TEST
			AS	4	35	2.29-2.44	15	23/15 cm
			AZ	5	35	3.05-3.51	0	26 34 48
			AZ	6	35	3.81-3.86	0	8/5 cm
4.1	Cobble or boulder	Light pink granitic cobble or boulder	DZ	7	37	4.11-4.42	10	
4.42		End of borehole						

ACRES

Drilling Report

JOB P8143.00
HOLE MB-BH2
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 11:00 May 15, 1987
FINISHED 15:00 May 15, 1987

METHOD OF SOIL NW driven casing
BW wash bored casing

CASING DIAM 89 mm O.D. to 1.52 m
73 mm O.D. to 2.44 m

DRILLING: ROCK n/a

CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.3
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	BH-1, 100 m
DRILLING PLATFORM	n/a
GROUND SURFACE	98.72 m
ROCK SURFACE	n/a
BOTTOM OF HOLE	96.18 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sand and gravel (fill)	Dark brown sand and gravel, compact to dense, wet	AS	1	35	0.00-0.46	23	2 7 10
			AS	2	35	0.76-1.22	8	12 16 20
1.4	Sandy silt	Dark brown sandy silt, some subangular fine gravel, trace clay, dense to very dense (till)	AS	3	35	1.52-1.90	10	23 39 31/38 cm
			AS	4	35	2.08-2.54	11	16 22 24
2.54		End of borehole						

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. BENNETT

APPROVED

LOGGED BY B. G. BENNETT

DATE November 1987

Form 318 A (1)

Drilling Report

AGRES

JOB P8143.00
HOLE MB-BH3
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 15:15 May 15, 1987
FINISHED 17:30 May 15, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.29 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.3
BEARING n/a
DIP Vertical

ELEVATIONS:
DATUM BH-1, 100 m
DRILLING PLATFORM n/a
GROUND SURFACE 99.3 m
ROCK SURFACE n/a
BOTTOM OF HOLE 96.92 m
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Gravelly sand (fill)	Light reddish brown gravelly medium sand, compact, wet	AS	1	35	0.00-0.46	13	5 11 11
0.6	Sand and gravel	Dark brown sand and gravel, some silt, trace clay, dense, wet (till)	AS	2	35	0.76-1.22	46	10 11 24
		1.52-1.65: dark brown medium sand (lens)	AS	3	35	1.52-1.98	18	22 25 16
		2.29-2.44: dark brown medium sand (lens)	AS	4	35	2.29-2.44	15	11/15 cm
2.44		End of borehole						

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett

LOGGED BY B. G. Bennett

APPROVED

DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.03
HOLE MB-BH4
SHEET 1 OF 2

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Mill Building (Site 2)

CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 08:15 May 16, 1987
FINISHED 13:15 May 16, 1987

METHOD OF DRILLING:
SOIL NW driven casing
BW driven casing
BW wash bored casing

CASING DIAM 89 mm O.D. to 1.09 m
73 mm O.D. to 1.09 m
73 mm O.D. to 2.29 m

ROCK BQ double tubed core barrel

CORE DIAM 60 mm O.D. to 2.59 m

LOCATION: LATITUDE see Figure 2.3
BEARING n/a
DIP Vertical

ELEVATIONS:
DATUM BH-1, 100 m
DRILLING PLATFORM n/a
GROUND SURFACE 99.39 m
ROCK SURFACE n/a
BOTTOM OF HOLE 96.80 m
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Gravel (fill)	Angular gravel, some sand, moist	AS	1	35	0.00-0.46	31	9 12 15
0.13	Sand and gravel	Dark brown sand and gravel, trace clay, compact, moist (till), faint solvent-type smell						
0.6	Sandy silt	Dark brown sandy silt, some gravel, trace clay, dense to very dense (till), faint solvent-type smell	AS	2	35	0.76-1.07	25	7 18/30 cm
			AS	3	35	1.52-1.90	20	21 35 16/38 cm

SAMPLING METHOD
*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER
N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett

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DATE November 1987

ACRES

Drilling Report

JOB P8143.00
HOLE MB-BH4
SHEET 2 OF 2

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE *TYPE	NO.	SIZE (mm)	DEPTH (m)	RET'D (cm)	PENE-TRATION TEST
			AS	4	35	2.29-2.43	14	23/14 cm
2.4		Light yellow sand-stone cobble or boulder	DZ	5	37	2.43-2.59	10	
2.59		End of borehole						

Drilling Report

JOB P8143.00
HOLE WD-BH1
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Waste Disposal (Site 3)

CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 13:00 May 18, 1987
FINISHED 15:15 May 18, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.74 m
CORE DIAM n/a

LOCATION: LATITUDE See Figure 2.4
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	BH-1, 100.0 m
DRILLING PLATFORM	n/a
GROUND SURFACE	99.47 m
ROCK SURFACE	n/a
BOTTOM OF HOLE	96.73 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Gravelly sand (fill)	Dark brown gravelly fine sand, some silt, very loose, moist	AS	1	35	0.00-0.46	13	2 2 2
0.6	Sandy silt	Dark brown sandy silt, some gravel, compact, moist (till)	AS	2	35	0.76-1.22	32	13 13 11
			AS	3	35	1.52-1.98	29	8 10 8
2.1	Gravelly silt	Dark brown gravelly silt, some fine sand, compact, moist (till)	AS	4	35	2.29-2.74	28	5 7 4
2.74	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett

APPROVED T J Boundsham

LOGGED BY B. G. Bennett

DATE November 1987

Drilling Report

AGRES

JOB P81143.00
HOLE WD-BH2
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Waste Disposal (Site 3)
CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 15:45 May 18, 1987
FINISHED 15:15 May 19, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.59 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.4
BEARING n/a
INITIAL DIP Vertical

ELEVATIONS:

DATUM	BH-1, 100 m
DRILLING PLATFORM	n/a
GROUND SURFACE	100.54 m
ROCK SURFACE	n/a
BOTTOM OF HOLE	97.95 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Debris (fill)	Mixture of organic matter insulation, and plastic, dry, loose	AS	1	35	0.00-0.46	10	2 2 3
			AZ	2	35	0.76-1.22	0	7 5 5
1.4	Gravelly Silt	Dark brown gravelly silt, some fine sand, compact to dense, wet, (till) faint smell of excrement	AS	3	35	1.52-1.98	25	11 9 37
		1.73 - 1.78: coarse sand	AS	4	35	2.29-2.74	43	7 6 9
2.74	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED BY B. G. Bennett

APPROVED
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE WD-BH3
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment

PROJECT Come-by-Chance Site Remediation

SITE Waste Disposal (Site 3)

CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 08:00 May 20, 1987
FINISHED 10:00 May 20, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.59 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.4
BEARING n/a
DIP Vertical

ELEVATIONS:
DATUM BH-1, 100 m
DRILLING PLATFORM n/a
GROUND SURFACE 96.25 m
ROCK SURFACE n/a
BOTTOM OF HOLE 93.67 m
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Organic	Dark brown peat, wet	AS	1	35	0.00-0.46	23	1 1 1
0.18	Sand and Gravel (fill)	Dark brown sand and gravel, very loose, wet						
0.6	Silty sand (fill)	Dark brown silty fine sand, some peat, very loose, wet becoming moist with depth	AS	2	35	0.76-1.22	8	1 1 1
			AS	3	35	1.52-1.98	5	1 1 2
2.1	Gravelly sand	Dark brown gravelly fine sand, some silt, trace clay, compact wet (till)	AS	4	35	2.29-2.59	28	9 11/30 cm
2.59	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett

APPROVED

LOGGED BY B. G. Bennett

DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE WD-BH4
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Waste Disposal (Site 3)
CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 13:15 May 20, 1987
FINISHED 09:30 May 21, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.13 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.4
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	Arbitrary
DRILLING PLATFORM	n/a
GROUND SURFACE	100.42 m
ROCK SURFACE	98.29 m
BOTTOM OF HOLE	98.29 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sandy gravel (fill)	Light brown sandy gravel, some sulphur fragments, loose, dry	AS	1	35	0.00-0.46	20	3 5 4
0.1	Clayey sand (fill)	Clayey medium sand, some wood fragments, moist						
0.7	Organic	Peat	AS	2	35	0.76-1.22	31	7 10 15
0.86	Gravelly silt	Light grayish brown gravelly silt, some fine sand, compact, moist (till)	AZ	3	35	1.52-1.93	0	9 7 20/41 cm
2.13	Bedrock							
2.13	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water-resistant bag
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED BY B. G. Bennett

APPROVED [signature]
DATE November 1987

Drilling Report

JOB P8143.00
HOLE WD-BH5
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Waste Disposal (Site 3)
CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 13:00 May 21, 1987
FINISHED 15:30 May 21, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.44 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.4
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	BH-1, 100 m
DRILLING PLATFORM	n/a
GROUND SURFACE	93.55 m
ROCK SURFACE	n/a
BOTTOM OF HOLE	91.11 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Gravelly sand (fill)	Light brown gravelly fine sand, some silt, compact, moist becoming dry with depth	AS	1	35	0.00-0.46	33	2 6 11
0.6	Gravelly silt	Light brown gravelly silt, some fine sand, dry and dense becoming moist and compact with depth (till)	AS	2	35	0.76-1.22	33	14 13 23
			AS	3	35	1.52-1.98	31	12 14 10
2.44	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
APPROVED

LOGGED BY B. G. Bennett
DATE November 1987

Form 318 A (1)

Drilling Report

JOB P8143.00
HOLE WD-BH6
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Waste Disposal (Site 3)
CONTRACTOR: Atlantic Geodrilling Ltd.

STARTED 17:30 May 21, 1987
FINISHED 19:00 May 21, 1987

METHOD OF DRILLING: SOIL BW driven casing
ROCK n/a

CASING DIAM 73 mm O.D. to 2.59 m
CORE DIAM n/a

LOCATION: LATITUDE see Figure 2.4
BEARING n/a
DIP Vertical

ELEVATIONS:

DATUM	BH-1, 100 m
DRILLING PLATFORM	n/a
GROUND SURFACE	91.82 m
ROCK SURFACE	n/a
BOTTOM OF HOLE	89.23 m
WATER LEVEL	see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Organic (fill)	Peat, some gravel	AS	1	35	0.00-0.46	5	1 1 3
0.6	Sandy gravel (fill)	Dark greyish brown sandy gravel, some silt, very loose, wet	AS	2	35	0.76-1.22	23	2 2 2
1.4	Gravelly silt (fill)	Dark brown gravelly silt, some fine sand, very loose, wet	AS	3	35	1.52-1.98	33	2 1 2
			AS	4	35	2.29-2.59	31	
2.59	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
LOGGED BY B. G. Bennett

APPROVED [signature]
DATE November 1987

Form 318 A (1)

Drilling Report

ACRES

JOB P8143.00
HOLE WD-BH7
SHEET 1 OF 1

CLIENT Government of Newfoundland and Labrador
Department of the Environment
PROJECT Come-by-Chance Site Remediation
SITE Waste Disposal (Site 3)
CONTRACTOR: Atlantic Geodrilling Ltd.
STARTED 19:30 May 21, 1987
FINISHED 21:00 May 21, 1987
METHOD OF DRILLING: SOIL BW driven casing
CASING DIAM 73 mm O.D. to 2.59 m
ROCK n/a
CORE DIAM n/a
LOCATION: LATITUDE see Figure 2.4
BEARING n/a
DIP Vertical
ELEVATIONS: DATUM BH-1, 100 m
DRILLING PLATFORM n/a
GROUND SURFACE 94.70 m
ROCK SURFACE n/a
BOTTOM OF HOLE 92.11 m
WATER LEVEL see Appendix C

DEPTH (m)	SOIL TYPE	DESCRIPTION	SAMPLE Type*	No.	Size (mm)	Depth (m)	Ret'd (cm)	Penetration Test
0.0	Sandy Silt (fill)	Dark brown sandy silt, some gravel, loose, wet	AS	1	35	0.00-0.46	5	1 2 6
0.6	Organic Matter (fill)	Dark brown peat, some silt, wet, oily smell	AS	2	35	0.76-1.22	18	3 5 2
0.84	Sandy silt (fill)	Dark greyish brown sandy silt, trace clay, loose, wet, oily smell						
1.4	Silty sand	Light brown silty fine sand, some fine gravel, compact, wet (till)	AS	3	35	1.52-1.98	37	8 11 11
			AS	4	35	2.29-2.59	24	4 8/30 cm
2.59	End of borehole							

SAMPLING METHOD

*A – split tube
B – thin wall tube
C – piston sampler
D – core barrel
E – auger
F – wash

SHIPPING CONTAINER

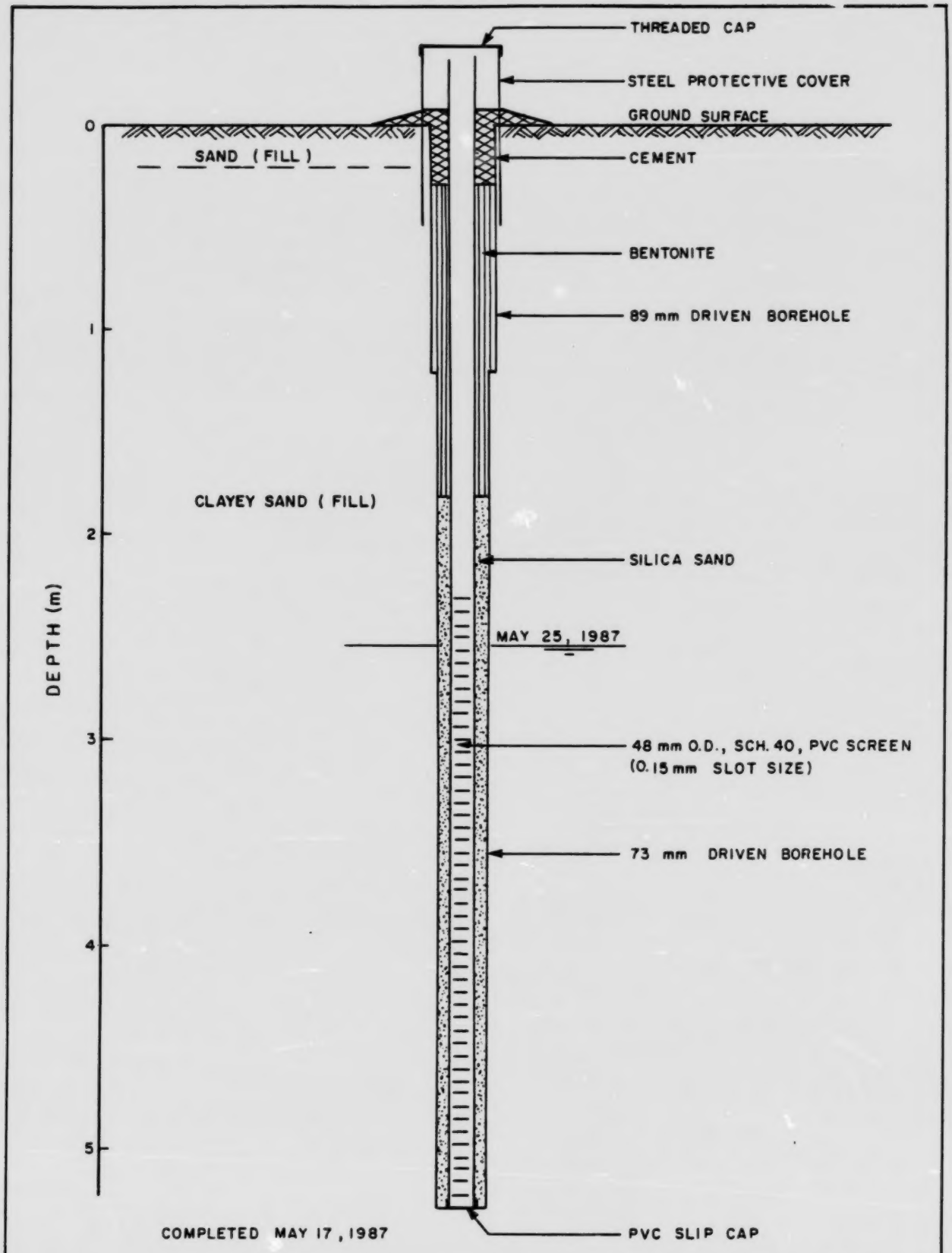
N – insert
O – tube
P – water content tin
Q – glass jar
R – cloth bag
S – plastic bag
Y – core box
Z – discarded

INSPECTOR B. G. Bennett
APPROVED
LOGGED BY B. G. Bennett
DATE November 1987

Form 318 A (1)

APPENDIX B

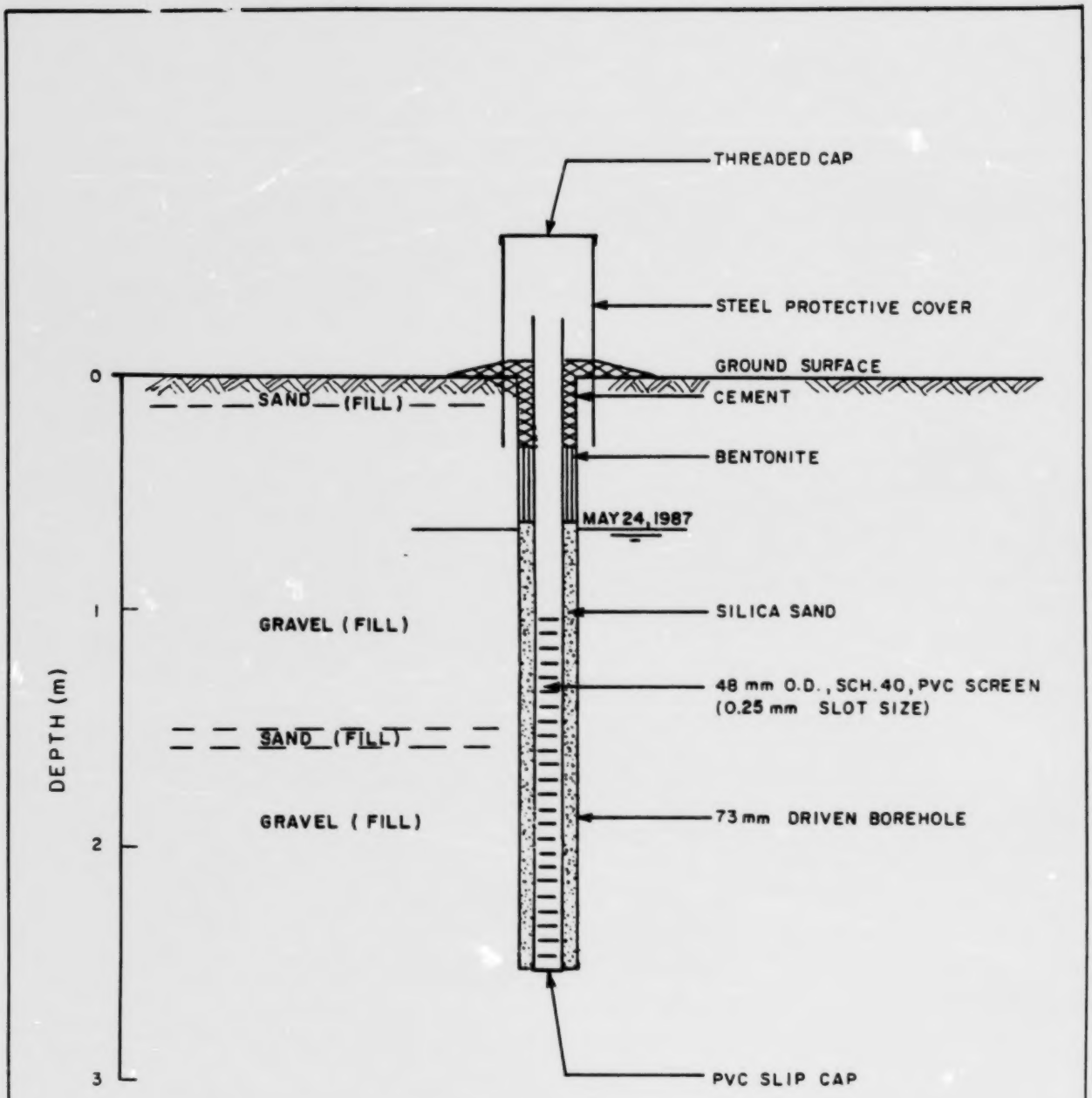
DRILLING REPORTS
MONITORING WELL COMPLETION DETAILS



NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

ACRES

MONITORING WELL COMPLETION DETAILS - TF BH 1

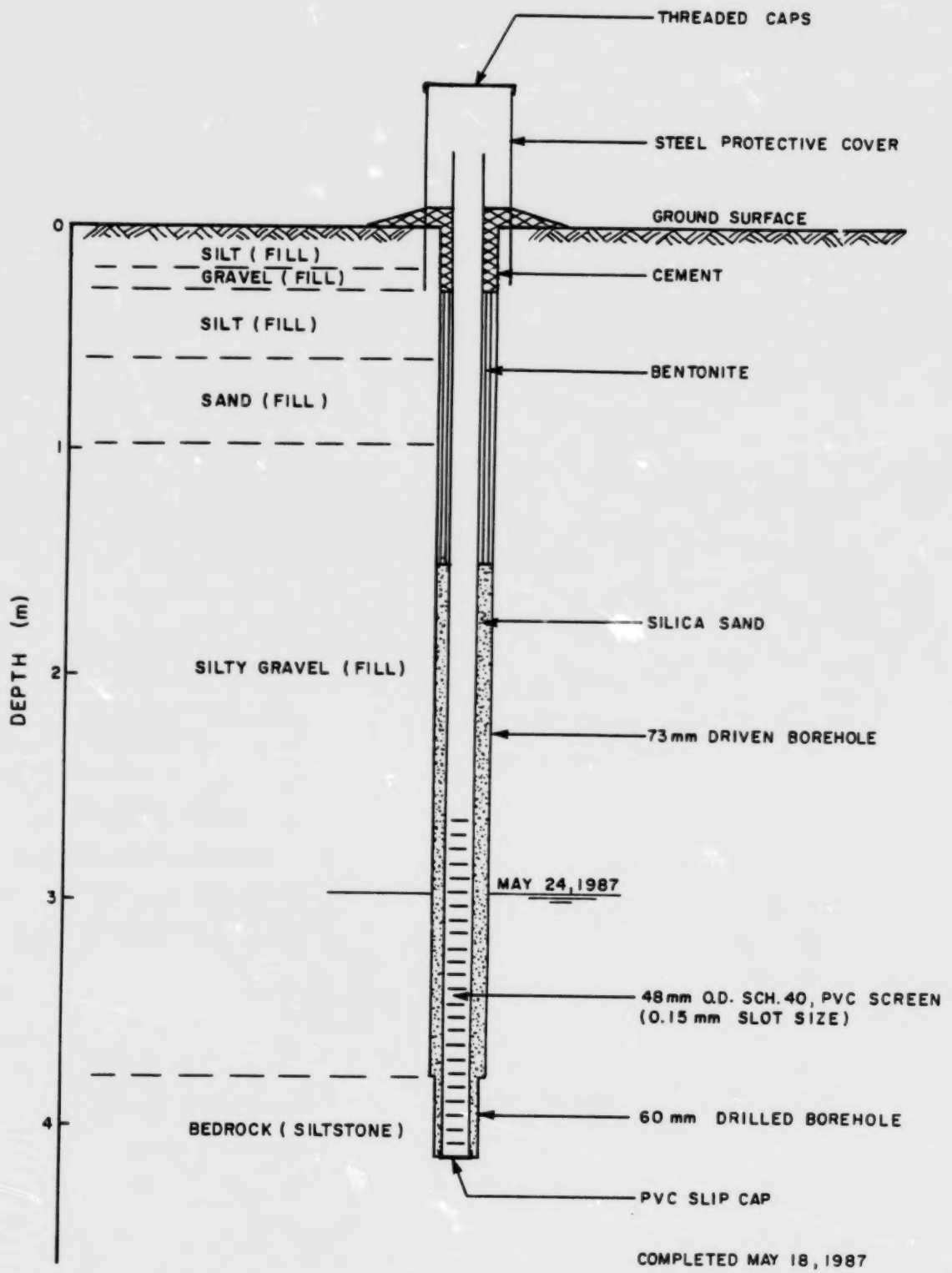


COMPLETED MAY 17, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

ACRES

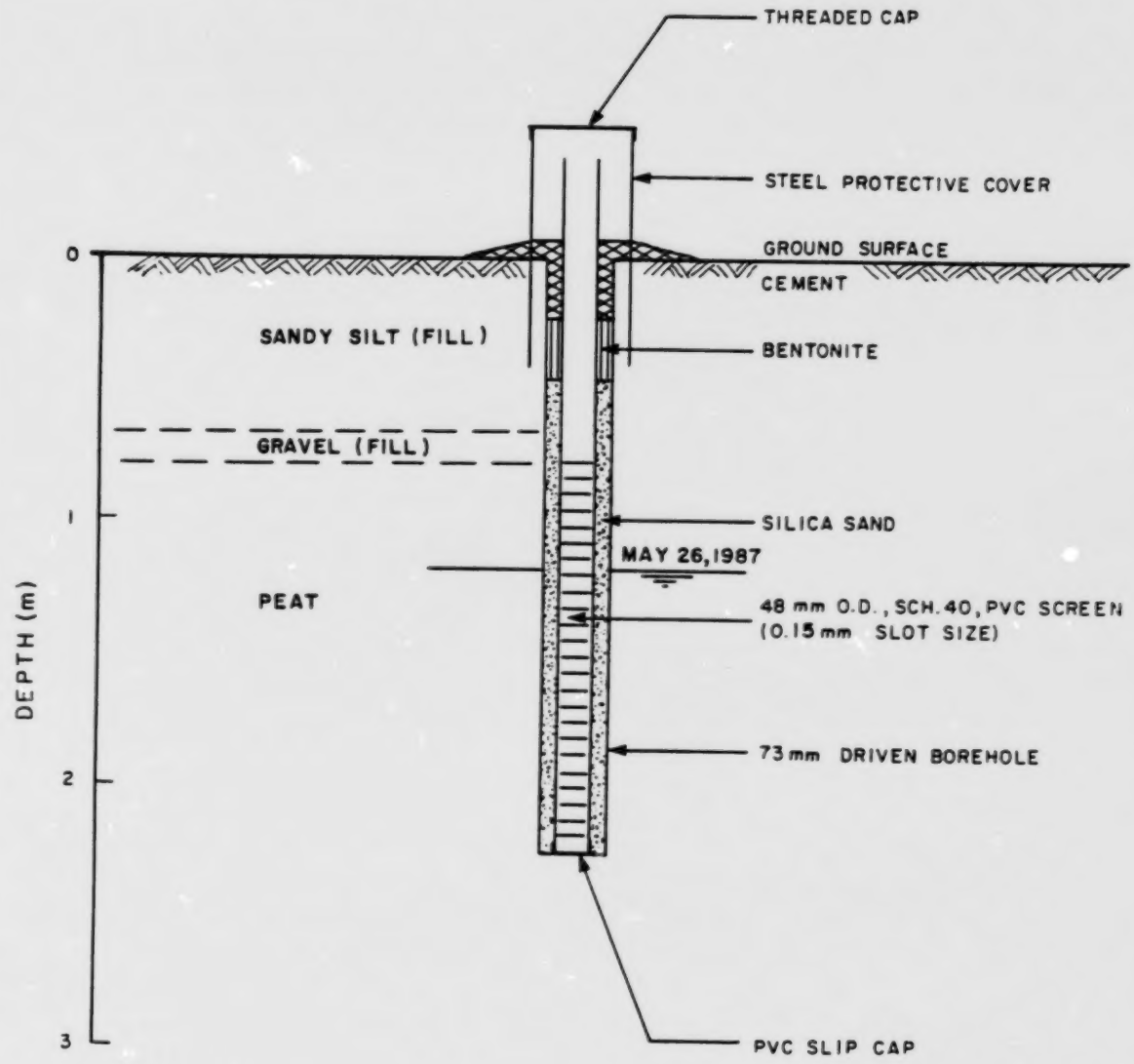
MONITORING WELL COMPLETION DETAILS - TF BH 2



NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

ACRES

MONITORING WELL COMPLETION DETAILS - TF BH 3

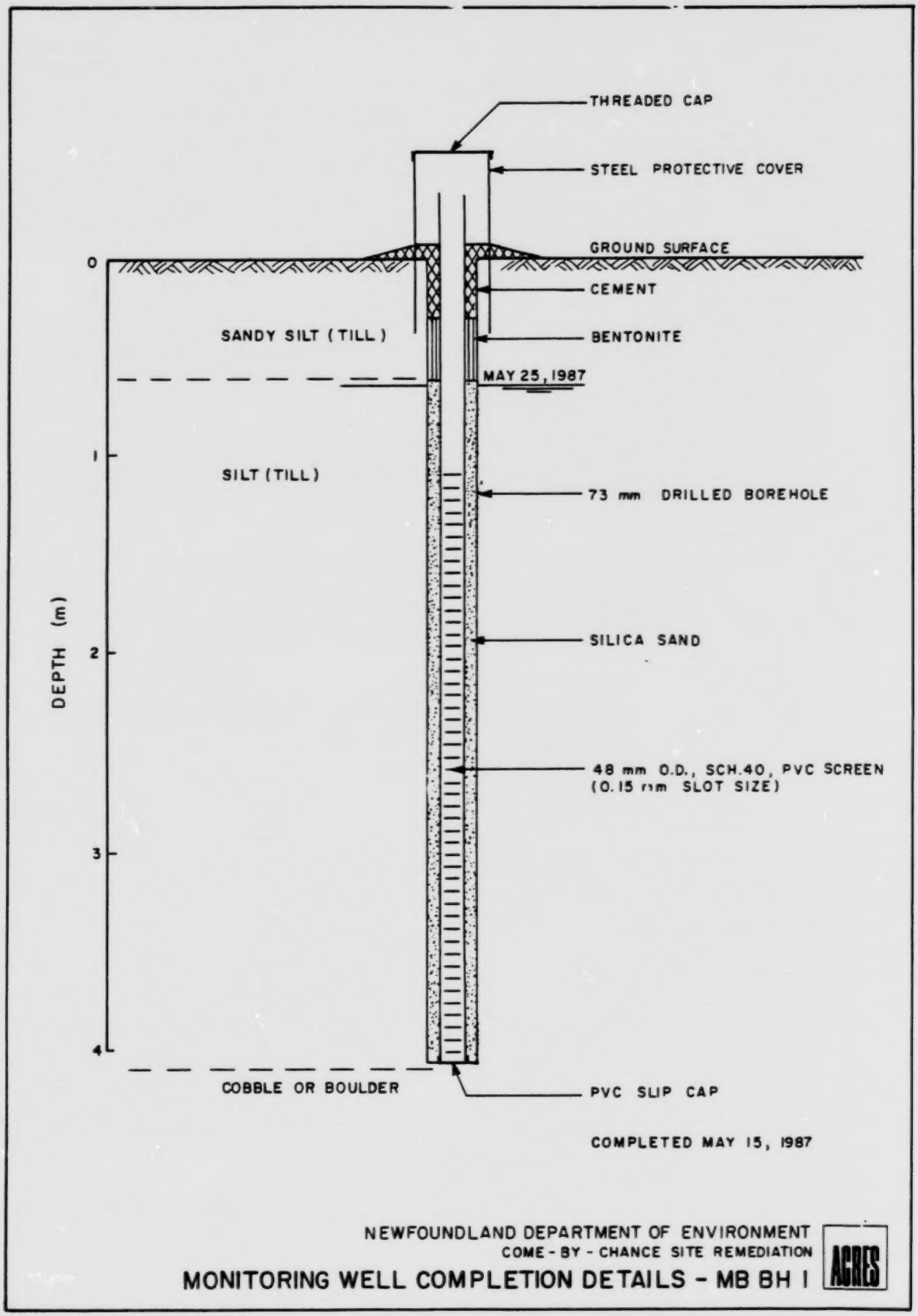


COMPLETED MAY 22, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - TF BH 4

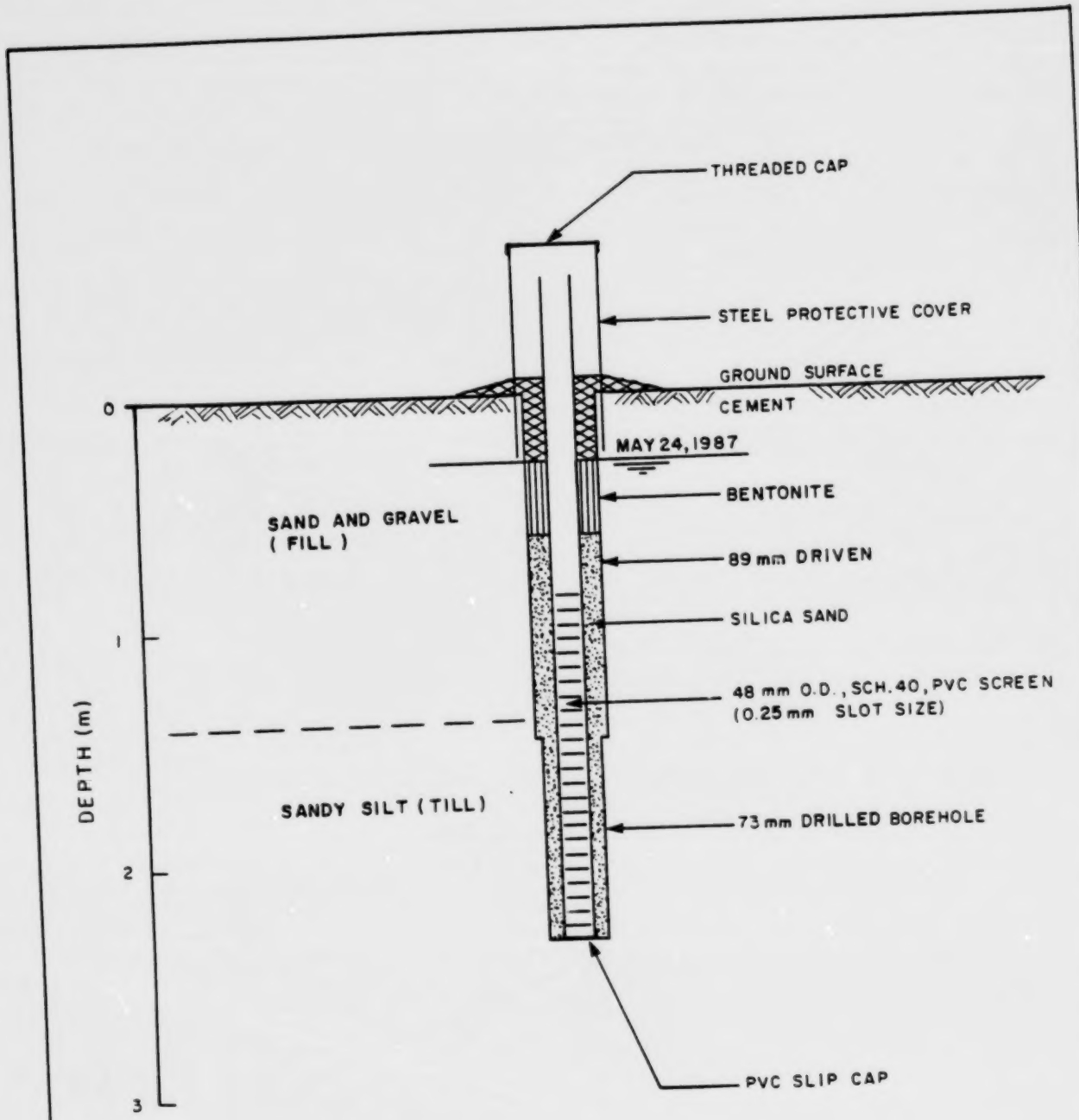
ACRES



NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - MB BH 1

ACRES

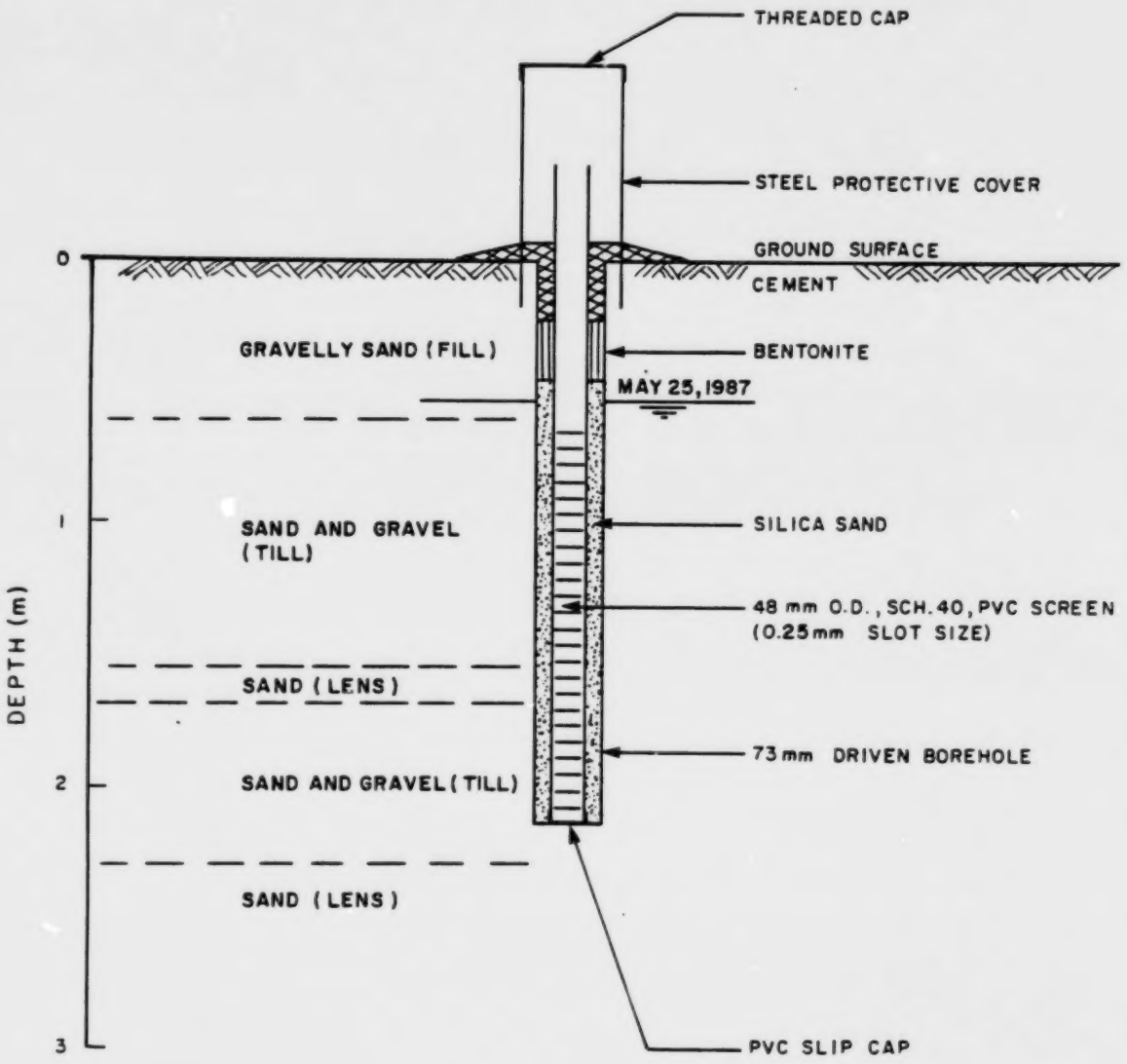


COMPLETED MAY 15, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS-MB BH 2

ACRES

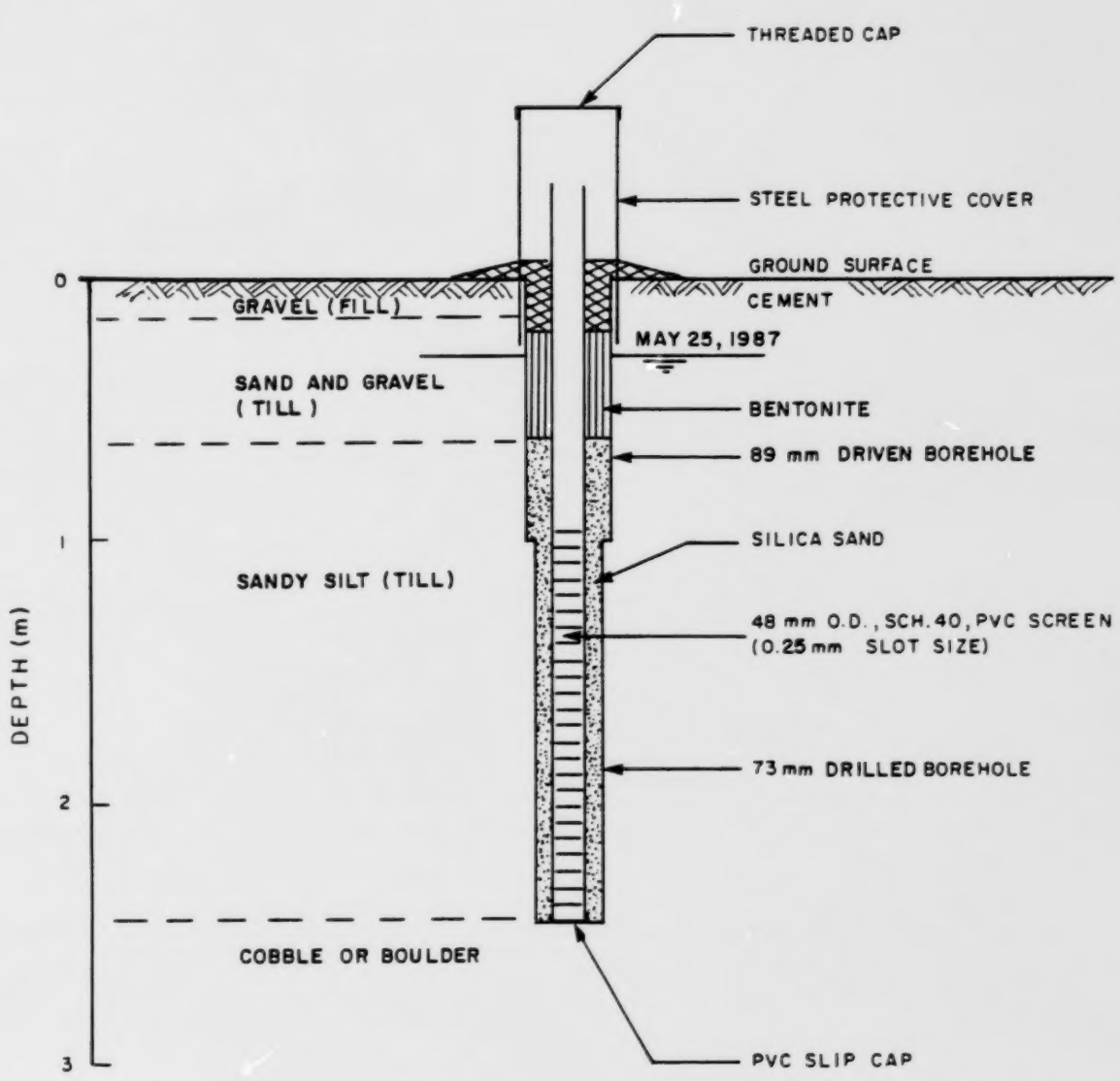


COMPLETED MAY 15, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS-MB BH 3

ACRES

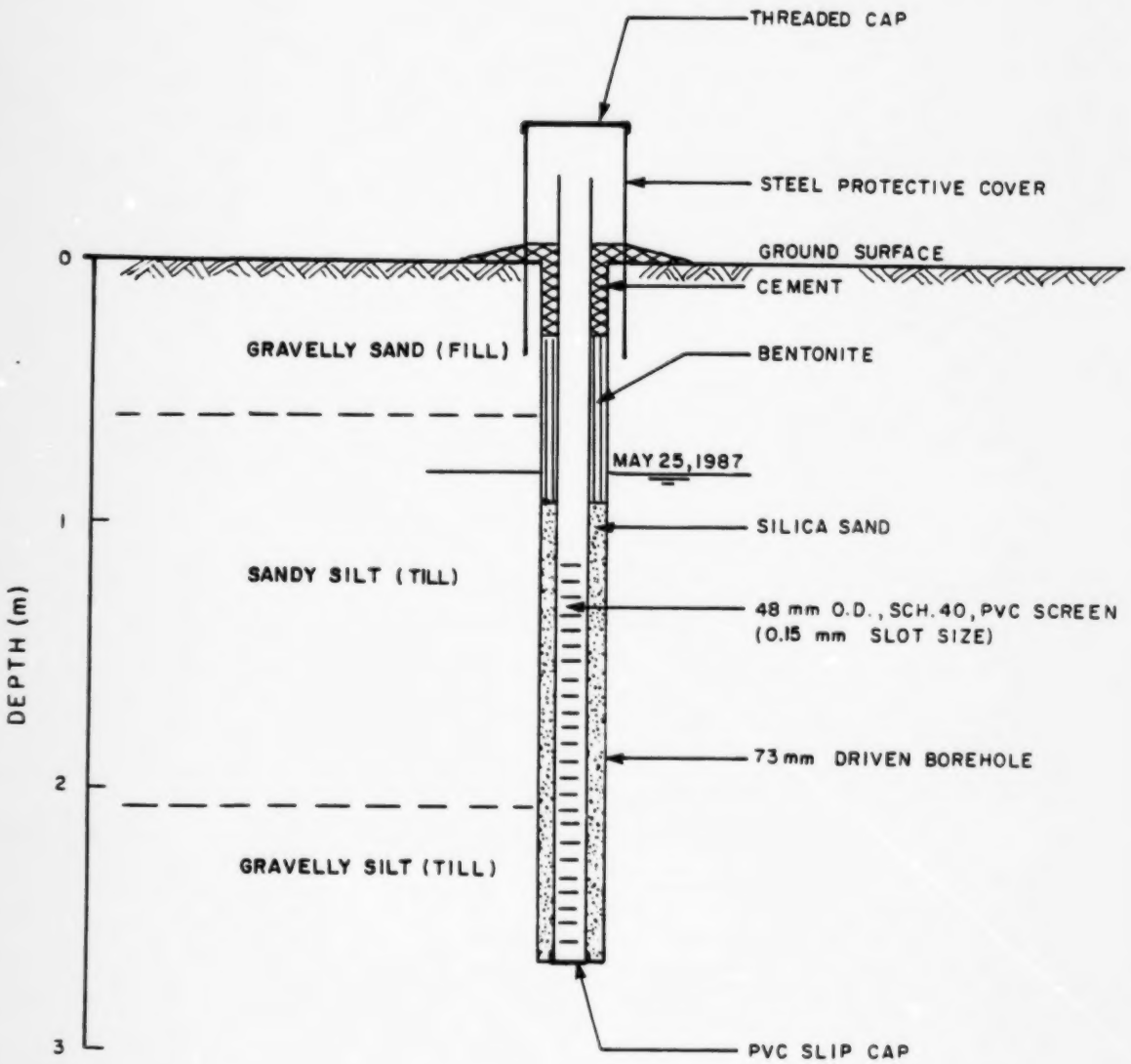


COMPLETED MAY 16, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - MB BH 4

ACRES



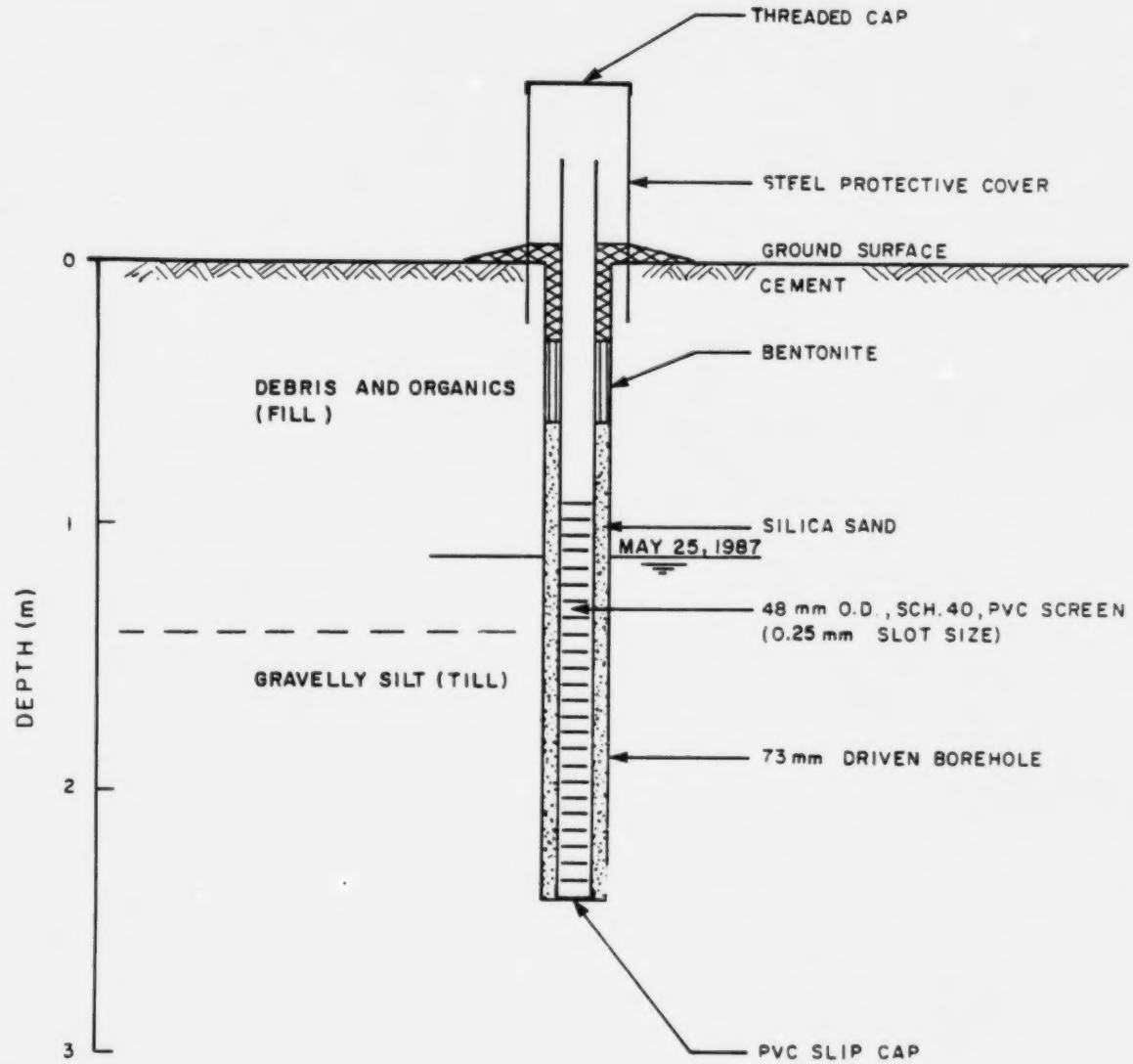
COMPLETED MAY 18 , 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT

COME - BY - CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - WD BH 1

ACRES

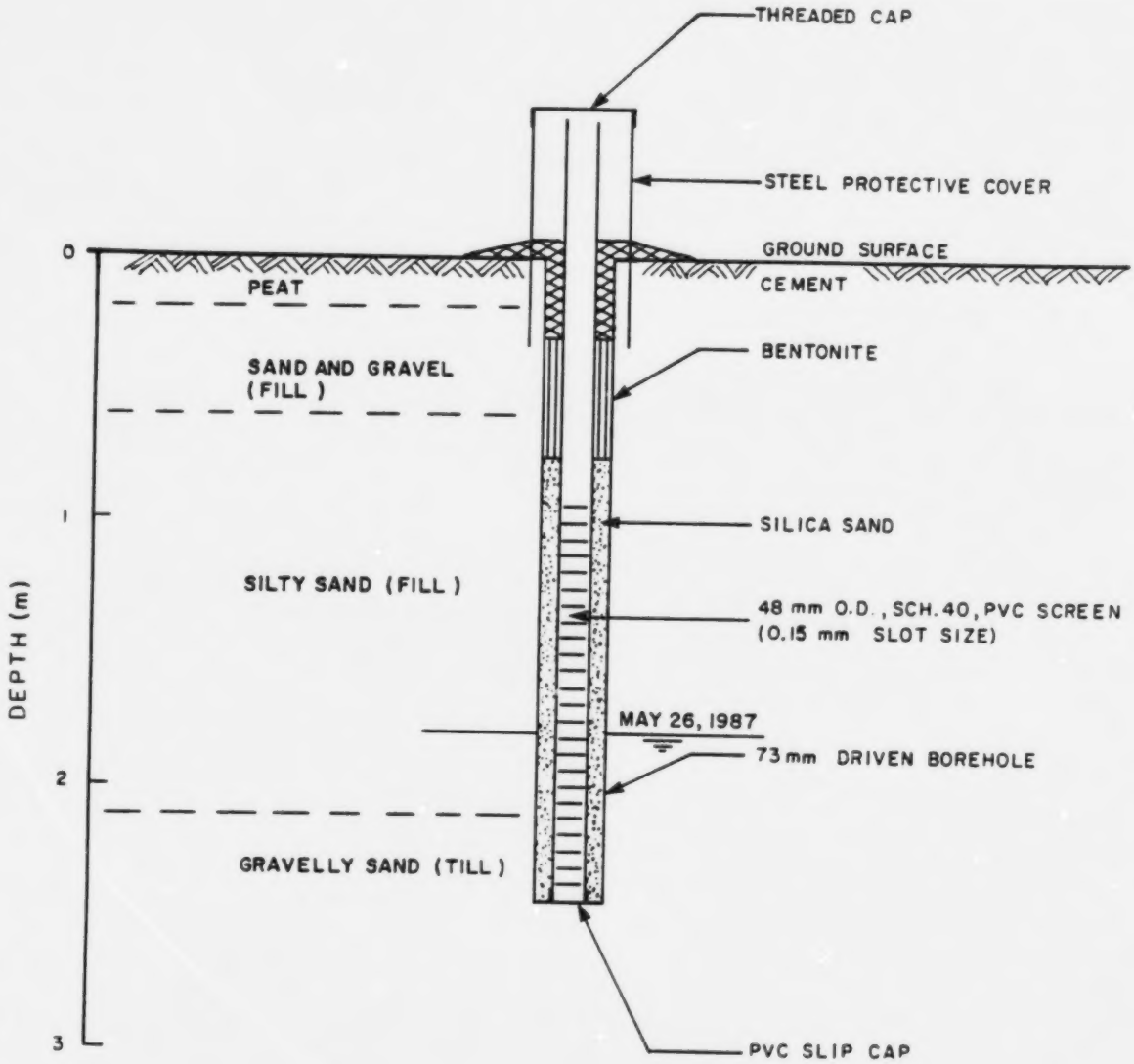


COMPLETED 19 MAY, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - WD BH 2

ACRES

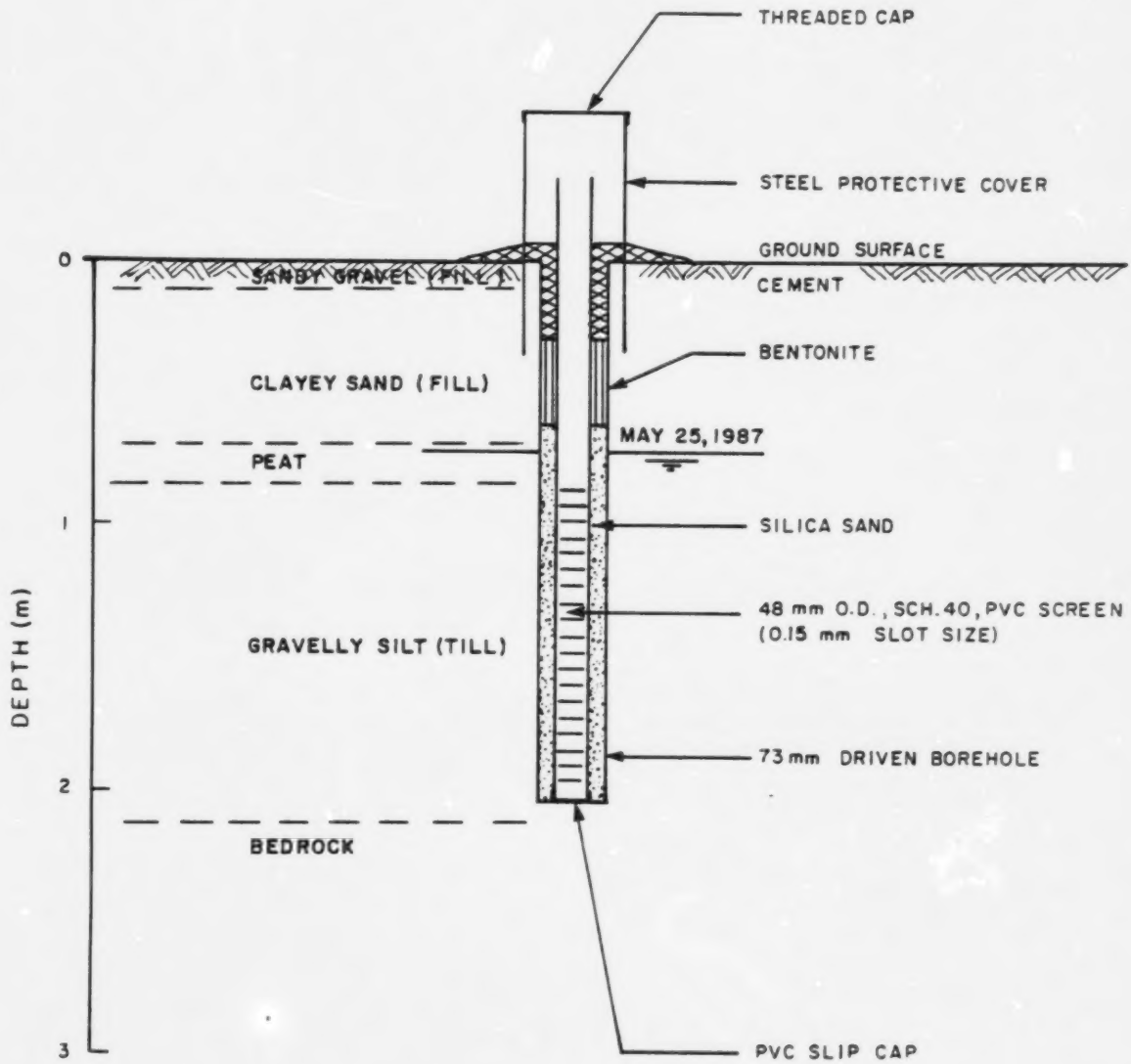


COMPLETED MAY 20, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS- WD BH 3

ACRES



COMPLETED MAY 21, 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS-WD BH 4

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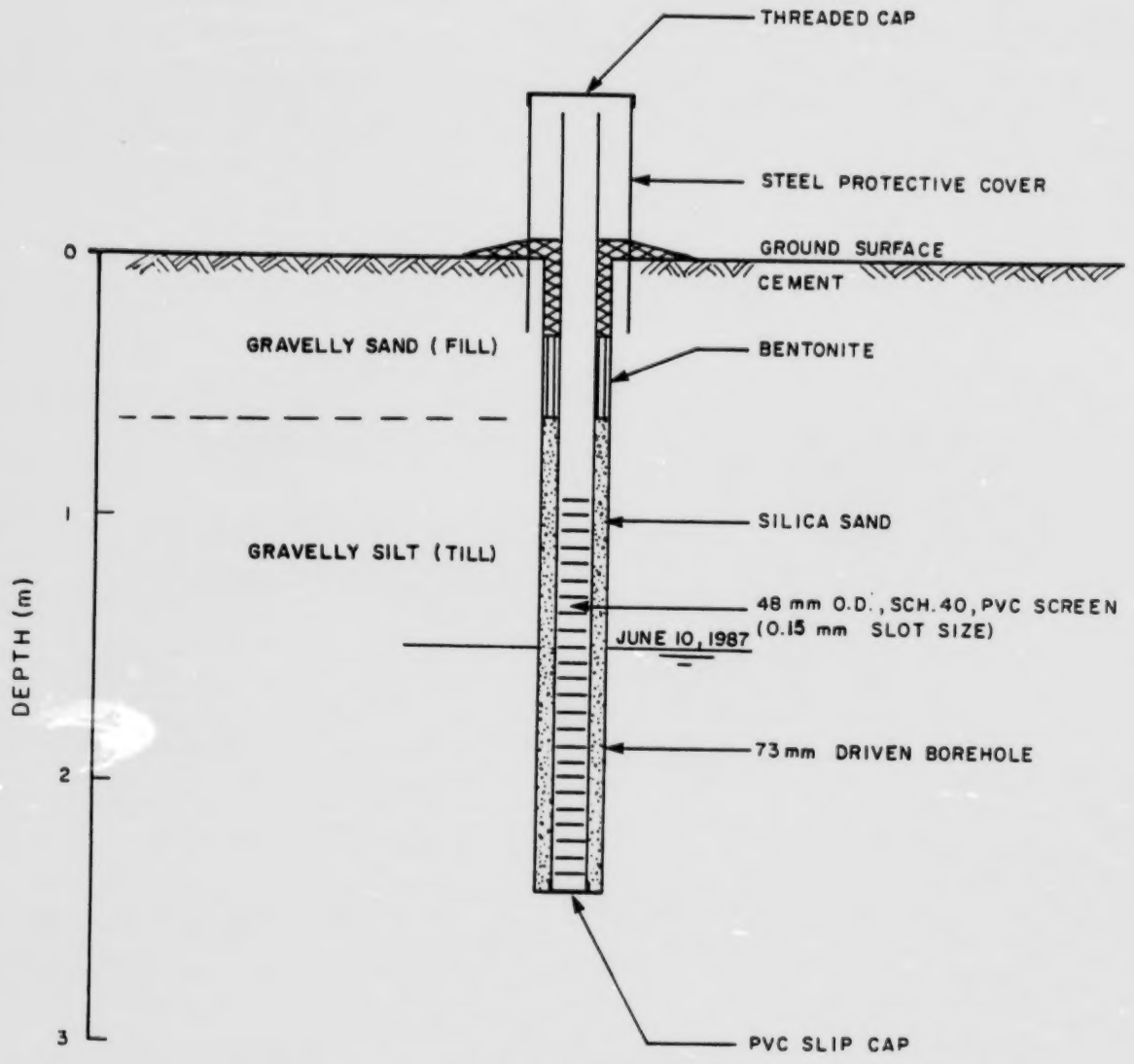
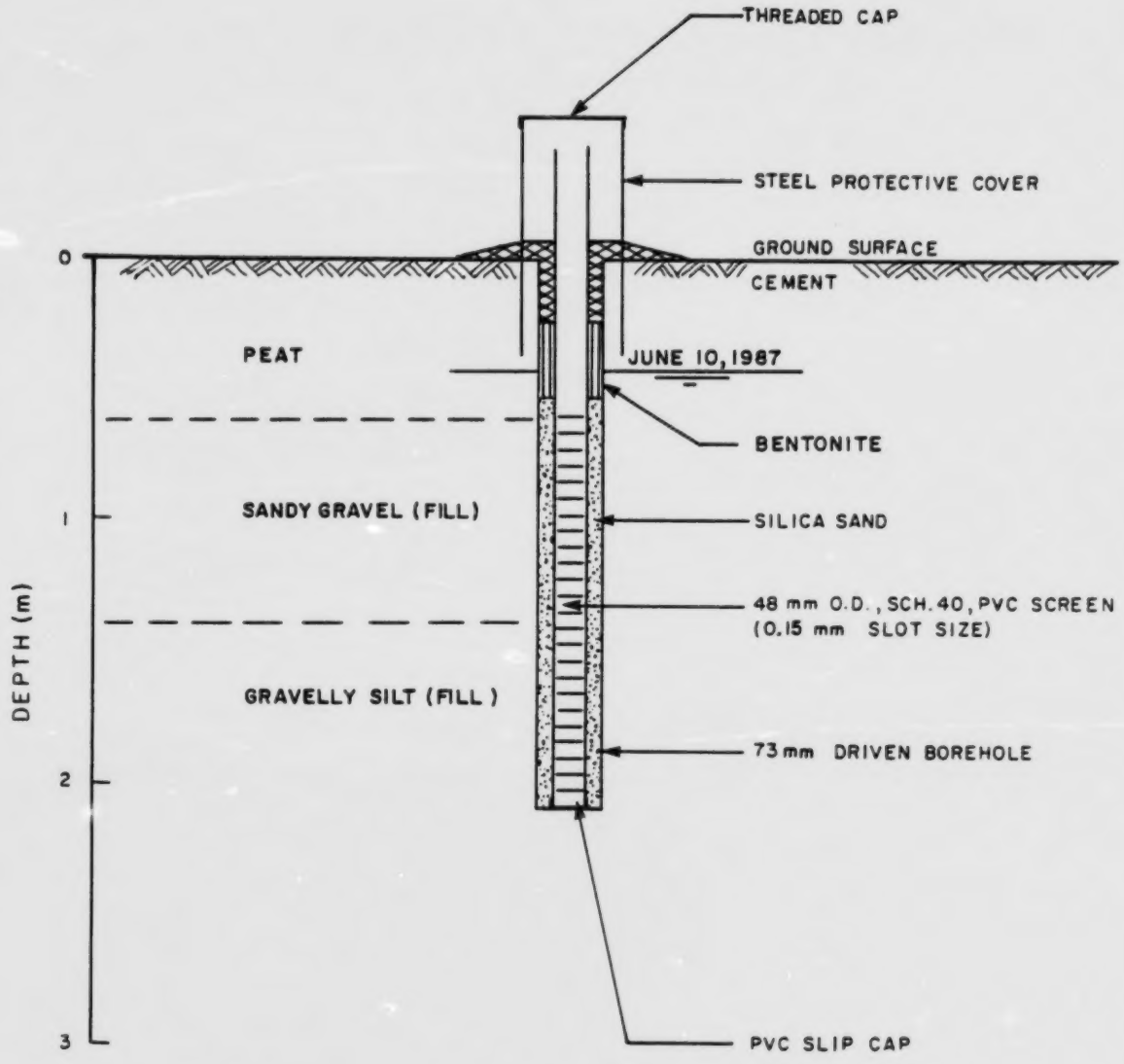


COMPLETED MAY 21 , 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS-WD BH 5

ACRES

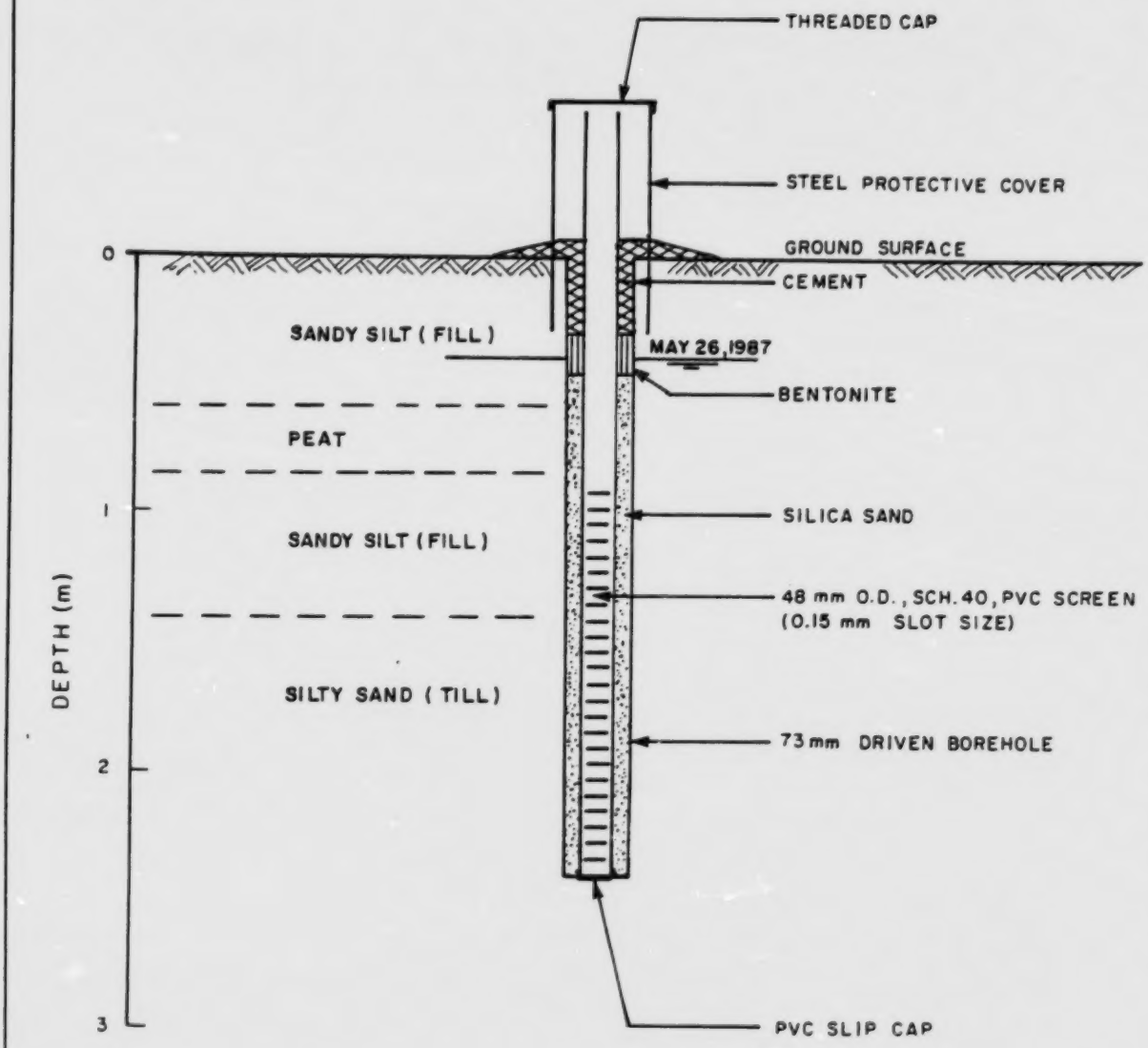


COMPLETED MAY 21 , 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME - BY - CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - WD BH 6

ACRES



COMPLETED MAY 21 , 1987

NEWFOUNDLAND DEPARTMENT OF ENVIRONMENT
COME-BY-CHANCE SITE REMEDIATION

MONITORING WELL COMPLETION DETAILS - WD BH 7

ACRES

APPENDIX C

BOREHOLE AND TESTPIT WATER LEVEL MEASUREMENTS

BOREHOLE WATER LEVEL MEASUREMENTS

Site - TF

Borehole No. - 1

Date	Time	Depth to Water (m btc*)	Remarks
May 17	09:15	-	Piezometer completed
May 20	20:05	2.89	Piezometer purged
May 23	09:30	2.88	
	19:40	2.92	
May 24	12:25	2.97	
May 25	08:20	2.96	
	16:40		Bail Test
	19:55	3.88	
May 26	08:30	3.13	
May 27	07:10	2.95	Piezometer purged
Jun 10		2.71	Piezometer purged
Jun 23		2.78	Piezometer purged
Jul 1		2.71	Piezometer purged
Jul 7	14:20	2.85	Piezometer purged
Jul 14		2.89	
Sept 8		3.30	
Sept 15		3.29	

*meters below top of casing; casing height 0.39 m above ground
Note: data after May 27 from DOE

Site - TF

Borehole No. - 2

Date	Time	Depth to Water (m btc*)	Remarks
May 17	13:15	-	Piezometer completed
May 20	20:30	1.19	Piezometer purged
May 23	09:35	1.23	
	19:45	1.24	
May 24	12:30	1.26	
	14:35		Bail test
May 25	08:30	1.27	
	20:00	1.28	
May 26	08:35	1.29	
May 27	07:45	1.30	Piezometer purged
Jun 10		1.50	
Jun 23		1.40	Piezometer purged
Jul 1	14:27	1.50	Piezometer purged
Jul 7		1.53	
Jul 14		1.60	
Sept 8		1.73	
Sept 15		1.66	

*meters below top of casing; casing height 0.61 m above ground.
Note: data after May 27 from DOE

Site - TF

Borehole No. - 3

Date	Time	Depth to Water (m btc*)	Remarks
May 18	09:45	-	Piezometer completed
May 20	19:35	3.53	Piezometer purged
May 23	09:30	3.62	
	19:40	3.63	
May 24	12:25	3.63	
	15:10		Bail test
May 25	08:20	3.64	
	19:55	3.63	
May 26	08:35	3.65	
May 27	07:30	3.66	Piezometer purged
Jun 10		3.70	
Jun 23		3.69	Piezometer purged
Jul 1	13:35	3.72	Piezometer purged
Jul 7		3.72	
Jul 14		3.77	
Sept 8		3.82	
Sept 15		3.79	

*meters below top of casing; casing height 0.64 m above ground
Note: data after May 27 from DOE

Site - TF

Borehole No. - 4

Date	Time	Depth to Water (m btc*)	Remarks
May 22	09:30	-	Piezometer completed
May 23	09:35	1.68	
	19:45	1.87	
May 24	12:30	1.71	
May 25	08:25	1.70	
	20:00	1.70	
May 26	08:30	1.69	
	08:45		Bail test
May 27	08:00	1.74	Piezometer purged
Jun 10		1.98	Piezometer purged
Jun 23		1.67	Piezometer purged
Jul 1		1.71	Piezometer purged
Jul 7	14:45	1.66	Piezometer purged
Jul 14	13:30	1.78	Piezometer purged
Sept 8		1.68	
Sept 15		1.66	

*meters below tip of casing; casing height 0.44 m above ground
Note: data after May 27 from DOE

Site - MB

Borehole No. - 1

Date	Time	Depth to Water (m btc*)	Remarks
May 15	10:20	-	Piezometer completed
May 20	18:00	1.04	Piezometer purged
May 23	10:00	1.23	
	20:00	1.19	
May 24	13:00	1.17	
May 25	08:50	1.19	
	12:45		Bail test
	20:20	1.34	
May 26	11:30	1.25	
May 27	09:05	1.34	Piezometer purged
Jun 10		1.60	Piezometer purged
Jun 23		1.22	Piezometer purged
Jul 1	12:23	1.45	Piezometer purged
Jul 7		1.42	
Jul 14	12:00	1.61	
Jul 20	10:45	2.04	
Aug 3	11:00	1.39 ?	
Sept 15		1.41	
Sept 24		1.15	

*meters below top of casing; casing height 0.54 m above ground
Note: data after May 27 from DOE

Site - MB

Borehole No. - 2

Date	Time	Depth to Water (m btc*)	Remarks
May 15	15:00	-	Piezometer completed
May 20	18:25	0.85	Piezometer purged
May 23	10:05	0.88	
	20:00	0.90	
May 24	12:55	0.94	
	15:55		Bail test
May 25	08:45	0.97	
	20:20	0.98	
May 26	11:30	1.01	
May 27	08:55	1.05	Piezometer purged
Jun 10		1.10	
Jun 23		0.98	Piezometer purged
Jul 1		1.15	Piezometer purged
Jul 7		1.07	
Jul 14	12:00	1.30	
Jul 20	10:45	1.43	
Aug 3	11:00	1.51	
Sept 15		1.34	
Sept 24		0.95	

*meters below top of casing; casing height 0.64 m above ground
Note: data after May 27 from DOE

Site - MB

Borehole No. - 3

Date	Time	Depth to Water (m btc*)	Remarks
May 15	17:30	-	Piezometer completed
May 20	18:45	1.12	Piezometer purged
May 23	10:10	1.17	
	19:55	1.21	
May 24	12:45	1.26	
May 25	08:40	1.29	
	13:30		Bail test
	20:15	1.30	
May 26	11:35	1.32	
May 27	08:30	1.35	Piezometer purged
Jun 10		1.31	Piezometer purged
Jun 23		1.34	Piezometer purged
Jul 1		1.42	Piezometer purged
Jul 7	10:20	1.35	Piezometer purged
Jul 14	12:00	1.53	
Jul 20	10:45	dry	
Aug 3	11:00	1.58	
Sept 15		1.47	
Sept 24		1.34	

*meters below top of casing; casing height 0.73 m above ground
Note: data after May 27 from DOE

Site - MB

Borehole No. - 4

Date	Time	Depth to Water (m btc*)	Remarks
May 16	13:15	-	Piezometer completed
May 20	19:05	0.81	Piezometer purged
May 23	10:10	0.75	
	19:55	0.84	
May 24	12:50	0.87	
May 25	08:45	0.95	
	14:50		Bail test
	20:15	1.07	
May 26	11:35	1.02	
May 27	08:45	1.07	Piezometer purged
Jun 10		0.73	Piezometer purged
Jun 23		0.96	Piezometer purged
Jul 1	12:53	1.07	Piezometer purged
Jul 7		0.78	
Jul 14	12:00	1.20	
Jul 20	10:45	1.37	
Aug 3	11:00	1.19	
Sept 15		1.04	
Sept 24		0.87	

*meters below top of casing; casing height 0.66 m above ground

Site - WD

Borehole No. - 1

Date	Time	Depth to Water (m btc*)	Remarks
May 18	15:15	-	Piezometer completed
May 23	10:25	1.39	
	20:10	1.36	
May 24	13:10	1.34	
May 25	08:55	1.35	
	09:55		Bail test
	20:30	2.39	
May 26	10:05	2.28	
May 27	09:45	2.10	
Jun 10		1.73	Piezometer purged
Jun 23		1.80	Piezometer purged
Jul 1		2.33	Piezometer purged
Jul 7		2.68	Piezometer purged
Jul 14	09:50	2.77	Piezometer purged
Jul 20	09:20	2.78	Piezometer purged
Aug 3	10:00	2.78	Piezometer purged
Sept 8		2.60	
Sept 15		2.61	
Sept 24		1.46	

*meters below top of casing; casing height 0.53 m above ground
Note: data after May 27 from DOE

Site - WD

Borehole No. - 2

Date	Time	Depth to Water (m btc*)	Remarks
May 19	15:15	-	Piezometer completed
May 23	10:30	1.78	
	20:15	1.78	
May 24	13:15	1.78	
May 25	09:00	1.80	
	10:30		Bail test
	20:35	1.80	
May 26	10:10	1.80	
May 27	10:00	1.81	Piezometer purged
Jun 10		1.88	Piezometer purged
Jun 23	12:30	1.82	Piezometer purged
Jul 1		1.88	Piezometer purged
Jul 7	11:15	1.94	Piezometer purged
Jul 14	10:09	2.23	
Jul 20	09:40	2.42	Piezometer purged
Aug 3	10:30	2.14	
Sept 8		2.31	
Sept 15		2.27	
Sept 24		1.94	

*meters below top of casing; casing height 0.68 m above ground
Note: data after May 27 from DOE

Site - WD

Borehole No. - 3

Date	Time	Depth to Water (m btc*)	Remarks
May 20	10:00	-	Piezometer completed
May 23	10:35	2.27	
	20:25	2.29	
May 24	13:40	2.34	
May 25	09:20	2.39	
	20:45	2.38	
May 26	10:20	2.39	
	10:30		Bail test
May 27	10:45	2.49	Piezometer purged
Jun 10		2.44	Piezometer purged
Jun 23		2.32	Piezometer purged
Jul 1		2.48	Piezometer purged
Jul 7		2.37	Piezometer purged
Jul 14	11:46	2.58	Piezometer purged
Jul 20	10:30	dry	
Aug 3	10:30	dry	
Sept 8		dry	
Sept 15		dry	
Sept 24		1.25	

*meters below top of casing; casing height 0.58 m above ground
Note: data after May 27 from DOE

Site - WD

Borehole No. - 4

Date	Time	Depth to Water (m btc*)	Remarks
May 21	09:30	-	Piezometer completed
May 23	10:30	1.26	
	20:15	1.29	
May 24	13:20	1.30	
May 25	09:05	1.28	
	11:15		Bail Test
	20:40	1.32	
May 26	10:10	1.29	
May 27	10:15	1.29	Piezometer purged
Jun 10		1.17	Piezometer purged
Jul 23		1.24	Piezometer purged
Jul 1		1.18	Piezometer purged
Jul 7	11:35	1.24	Piezometer purged
Jul 14	10:50	1.26	
Jul 20	10:15	1.37	
Aug 3	10:30	1.19	
Sept 8		1.32	
Sept 15		1.27	
Sept 24		1.13	

*meters below top of casing; casing height 0.57 m above ground
Note: data after May 27 from DOE

Site - WD

Borehole No. - 5

Date	Time	Depth to Water (m btc*)	Remarks
May 21	13:30	-	Piezometer completed
May 23	10:40	2.88	
	20:20	2.83	
May 24	13:30	2.76	
May 25	09:15	2.70	
	20:40	2.67	
May 26	10:20	2.63	
May 27	10:30	2.57	
Jun 10		2.14	Piezometer purged
Jun 23		2.17	Piezometer purged
Jul 1		2.40	Piezometer purged
Jul 7		2.65	Piezometer purged
Jul 14	11:10	2.72	Piezometer purged
Jul 20	09:50	2.85	Piezometer purged
Aug 3	10:15	dry	
Sept 8		dry	
Sept 15		dry	
Sept 24		dry	

*meters below top of casing; casing height 0.62 m above ground
Note: data after May 27 from DOE

Site - WD

Borehole No. - 6

Date	Time	Depth to Water (m btc*)	Remarks
May 21	19:00	-	Piezometer completed
May 23	10:45	2.33	
	20:15	2.25	
May 24	13:20	2.12	
May 25	09:05	1.98	
	20:35	1.80	
May 26	10:15	1.81	
May 27	10:25	1.69	
Jun 10		0.96	Piezometer purged
Jun 23		0.87	Piezometer purged
Jul 1		1.36	Piezometer purged
Jul 7		1.75	Piezometer purged
Jul 14	10:35	1.74	Piezometer purged
Jul 20	09:36	1.98	Piezometer purged
Aug 3	10:30	1.90	
Sept 8		1.95	
Sept 15		1.39	
Sept 24		0.98	

*meters below top of casing; casing height 0.55 m above ground
Note: data after May 27 from DOE

Site - WD

Borehole No. - 7

Date	Time	Depth to Water (m btc*)	Remarks
May 21	20:50	-	Piezometer completed
May 23	10:50	0.83	
	20:30	0.89	
May 24	13:45	0.94	
May 25	09:25	0.97	
	20:50	1.00	
May 26	10:25	1.00	
	11:00		Bail test
May 27	10:55	1.02	Piezometer purged
Jun 10		0.97	Piezometer purged
Jun 23		0.97	Piezometer purged
Jul 1		1.02	Piezometer purged
Jul 7	12:35	0.97	Piezometer purged
Jul 14	12:00	1.11	
Jul 20	10:30	1.13	
Aug 3	10:30	1.11	
Sept 15		1.01	
Sept 24		0.97	

*meters below top of casing; casing height 0.61 m above ground
Note: data after May 27 from DOE

TESTPIT WATER LEVEL MEASUREMENTS

Site - TF

Date	Time	Depth to Water (m btc*) TP2	TP3
May 27	08:10-08:20	2.71	dry
Jun 10		2.78	dry
Jun 23		2.71	dry
Jul 1		2.79	dry
Jul 7		2.74	dry
Jul 14	13:30-13:45	2.77	dry
Sept 8		2.71	3.51
Sept 15		2.76	3.51

Site - MB

Date	Time	Depth to Water (m btc*) TP2	TP4
May 24	12:45-12:55	2.80	0.77
25	08:40-08:50	2.25	0.79
27	08:40-08:55	1.81	0.86
Jun 10		1.55	0.85
Jun 23		1.42	0.81
Jul 1		1.57	0.93
Jul 7		1.47	0.82
Jul 14	12:00-12:15	1.80	1.12
Jul 20	10:45-11:15	2.02	1.25
Aug 3	11:00-11:15	1.92	1.26
Sept 15		1.53	1.11
Sept 24		1.36	0.75

Site - WD

Date	Time	Depth of Water (m btc*) TP1	TP2	TP3	TP4	TP5	TP6	TP8
May 23	11:00-11:15	1.35	2.55	1.73	0.85	2.52	1.78	dry
	20:10-20:25	1.36	2.57	1.74	0.86	2.53	1.78	-
May 24	13:10-13:45	1.39	2.56	1.75	0.89	2.54	1.81	dry
May 25	08:55-09:20	1.42	2.57	1.76	0.91	2.56	1.74	-
May 27	10:20-11:05	1.51	2.59	1.77	0.97	2.58	1.71	dry
Jun 10		1.66	2.66	1.83	1.07	2.75	1.65	dry
Jun 23		1.51	2.63	1.76	1.03	2.62	1.60	dry
Jul 1		1.83	2.67	1.80	1.19	2.73	1.75	dry
Jul 7		1.83	2.76	1.80	1.17	2.80	1.84	dry
Jul 14	10:50-12:15	2.00	2.89	1.81	1.32	2.83	2.09	dry
Jul 20	10:00-10:45		2.83	1.86	1.39	2.90	2.26	dry
Aug 3	10:30-11:00	2.18	2.81	1.81	1.47	2.90	2.35	dry
Sept 8		2.25	dry	1.82	1.37	2.90	2.32	-
Sept 15		2.23	dry	1.83	1.50	2.86	2.07	dry
Sept 24		1.60	dry	1.78	0.95	2.84	2.22	dry

*meters below top of casing
Note: data after May 27 from DOE

APPENDIX D

BOREHOLE PURGING SUMMARY
WATER QUALITY FIELD MEASUREMENTS

BOREHOLE PURGING SUMMARY AND
GROUNDWATER QUALITY FIELD MEASUREMENTS

Site	Borehole No.	Date	Volume Removed (L)	Borehole Volume (L)	Temp. (°C)	Specific Conductance (umho/cm)	pH
TF	1	May 20	4.8	3.6	2.9	830	
		25*	2.4		5.4	850	
		27	3.0		4.2	780	
		Jun 10	5.1				
		23	5.1				
		Jul 1	4.3		7.5	1381	6.15
		7	2.5		6.5	1308	6.34
	2	May 20	40.0	2.4	4.7	740	
		24*	18.5		5.2	760	
		27	20.0		4.8	730	
		Jun 23	3.0				
		Jul 1	1.2		9.5	1226	5.95
	3	May 20	40.0	1.5	4.3	148	
		24*	5.6		4.9	273	
		27	20.0		5.1	165	
		Jun 23	3.0				
		Jul 1	1.2		8.6	762	5.37
	4	May 26*	1.7	1.4	7.4	95	
		27	0.9		5.0	75	
		Jun 10	1.1				
		23	1.2				
		Jul 1	1.3		10.3	139	4.78
		7	1.8		11.3	144	4.43
		14	0.8				

*Bail test

Note: data after May 27 from DOE

Site	Borehole No.	Date	Volume Removed (L)	Borehole Volume (L)	Temp. (°C)	Specific Conductance (umho/cm)	pH
MB	1	May 20	7.8	4.4	7.8	260	
		25*	2.5		8.2	413	
		27	8.1		6.4	363	
		Jun 10	4.9				
		23	3.0				
		Jul 1	1.2		10.0	768	6.92
	2	May 20	60.0	2.8	7.1	150	
		24*	17.5		7.2	179	
		27	20.0		7.1	166	
		Jun 23	3.0				
		Jul 1	1.4		11.8	434	6.33
	3	May 20	2.2	2.1	6.8	208	
		25*	1.8		10.3	215	
		27	1.6		7.5	188	
		Jun 10	2.4				
		23	1.6				
		Jul 1	3.8		12.7	382	6.28
		7	2.5		13.2	401	7.2
	4	May 20	9.3	2.8	6.9	620	
		25*	6.8		8.2	600	
		27	6.7		7.3	600	
		Jun 10	8.4				
		23	3.0				
		Jul 1	1.2		12.1	1425	6.45

*Bail test
Note: data after May 27 from DOE

Site	Borehole No.	Date	Volume Removed (L)	Borehole Volume (L)	Temp. (°C)	Specific Conductance (umho/cm)	pH
WD	1	May 25*	2.0	2.3	9.0	476	
		Jun 10	1.4				
		23	1.3				
		Jul 1	1.0		8.5	1482	6.78
		7	0.5		10.5	1646	6.45
		14	0.5				
		20	0.4				
		Aug 3	0.6				
	2	May 25*	1.8	1.7	8.5	340	
		27	2.1		7.7	308	
		Jun 10	1.5				
		23	2.0				
		Jul 1	1.8		9.0	650	6.28
		7	1.8		11.4	488	5.78
		20	1.3				
	3	May 26*	0.4	0.8	11.8	310	
		27	0.4		9.6	242	
		Jun 10	0.4				
		23	0.7				
		Jul 1	0.6				
		7	0.8				
		14	0.5				
	4	May 25*	1.5	1.7	7.9	730	
		27	1.5		6.5	720	
		Jun 10	1.6				
		23	1.7				
		Jul 1	2.6		9.0	1355	6.04
		7	2.5		11.4	1390	5.66
	5	Jun 10	1.4	1.2			
		23	1.1				
		Jul 1	1.0		9.7	553	5.9
		7	0.6		10.9	587	5.65
		14	0.4				
		20	0.3				

*Bail test
Note: data after May 27 from DOE

Site	Borehole No.	Date	Volume Removed (L)	Borehole Volume (L)	Temp. (°C)	Specific Conductance (umho/cm)	pH
	6	Jun 10	1.6	2.4			
		23	2.2				
		Jul 1	2.0		10.5	1513	6.34
		7	1.4		11.0	1594	5.94
		14	1.8				
		20	0.9				
	7	May 26*	2.2	2.6	8.0	230	
		27	2.3		6.9	200	
		Jun 10	2.6				
		23	2.5				
		Jul 1	2.9		10.0	238	6.21
		7	2.5		12.1	244	5.98

*Bail test
Note: data after May 27 from DOE

SURFACE WATER QUALITY FIELD MEASUREMENTS

Site		Date	Time	Temp. (°C)	Specific Conductance (umhos/cm)
TF	Pond south of Tank farm site	May 16	14:20	13.1	85
	Creek east of Tank farm site	May 16	14:30	12.5	57
MD	Creek south of Mill Building site	May 14	08:10	11.2	32
		May 15	21:40	10.9	32
	Pond north side of Mill Bldg.	May 14	08:50	9.1	121
		May 15	21:30	9.7	134
WD	Pond at Waste Disposal Site	May 15	20:15	11.5	370
	Quarry pit pond north of Waste disposal site	May 15	21:50	11.7	231

APPENDIX E

SAMPLING RATIONALES AND METHODS OF ANALYSIS

APPENDIX E.1

COME BY CHANCE PROJECT SAMPLING
RATIONALES AND METHODS OF ANALYSIS

Parameter	Analytes	Reason for Testing	Method of Analysis
General Parameters (water)	Specific conductance pH	Indicator parameters for general water quality	"Specific Conductance (Whetstone Bridge, Conductance Cell)" Environment Canada (Naquadat No. 02041)."pH (Electrometric)" Environment Canada (Naquadat No. 10301).
Major Ions (water)	Calcium Magnesium Sodium Potassium Alkalinity Sulfate Chloride NItrate	Major ion balance Determination of predominant species of inorganic salt	"Calcium (Atomic Adsorption)" Environment Canada (Naquadat No. 20103). "Magnesium (Atomic Adsorption)" Environment Canada (Naquadat No.12102). "Sodium (Automated Flame Photometric)" Environment Canada (Naquadat No. 11103). "Potassium (Automated Flame Photometric)" Environment Canada (Naquadat No.19103)."Alkalinity (Electrometric Titration) "Environment Canada (Naquadat No. 10101). "Sulphate (Automated Methylthymol Blue)" Environment Canada (Naquadat No. 16306). "Chloride (Automated - Thiocyanate)" Environment Canada (Naquadat No. 17203). "Nitrogen: Nitrate + Nitrite (Automated Cadmium Reduction)" Environment Canada (Naquadat No. 07106).
Metals	Lead Vanadium Zinc Arsenic Cadmium Chromium Copper Nickel	Heavy metals most closely associated with petroleum refining Heavy metals associated to a lesser extent with oil refining	Soil "Non-Residual Metals in Sediments (0.5 N Hydrochloric Acid Extraction)" Environment Canada Lead (Naquadat No. 8205). Vanadium (No Naquadat No.). Zinc (Naquadat No. 30054). Cadmium (Naquadat No. 48054). Chromium (Naquadat No. 24054). Copper (Naquadat No. 29054). Iron (Naquadat No. 26054). Nickel (Naquadat No. 28054). "Arsenic and Selenium in Sediment (Flameless Atomic Absorption, Hydride)" Environment Canada (Naquadat No. 33050).

Appendix E.1
Come by Chance Project Sampling
Rationales and Methods of Analysis - 2

Parameter	Analytes	Reason for Testing	Method of Analysis
			Water "Lead (Atomic Adsorption)" Environment Canada (Naquadat No. 82101). "Vanadium (Atomic Adsorption)" Environment Canada (Naquadat No. 23101). "Zinc (Atomic Adsorption)" Environment Canada (Naquadat No. 30104). "Arsenic (Flameless Atomic Absorption)" Environment Canada (Naquadat No. 33304). "Cadmium (Atomic Adsorption)" Environment Canada (Naquadat No. 48101). "Chromium (Atomic Adsorption)" Environment Canada (Naquadat No. 24052). "Copper (Atomic Adsorption)" Environment Canada (Naquadat No. 29106). "Nickel (Atomic Adsorption)" Environment Canada (Naquadat No. 28101).
Oil and Grease	Solvent Extractables	Fast, gross determination of presence and quantification of greases, oils and light oil residuals from a wide range of sources	Soil "Oil and Grease in Sediment (Gravimetric)" Environment Canada (Naquadat No. 06526). Water "Oil and Grease (Gravimetric)" Environment Canada (Naquadat No. 06521).
Phenolics	Total phenols distinguishable by stated method	Indicator of gross organic chemical contamination	Soil H_3PO_3 distillation followed by "Phenolics (Calorimetric - Automated 4-Aminoantipyrene)" Environment Canada (Naquadat No. 06533). Water "Phenolics (Calorimetric - Automated 4-Aminoantipyrene)" Environment Canada (Naquadat No. 06533).
PCBs (soil)	Common PCBs	As a confirmation of absence only	Environment Canada "Organochlorinated Pesticides and PCBs in Sediments" - Gas Chromatographic (Naquadat No. 18169).

Appendix E.1
Come by Chance Project Sampling
Rationales and Methods of Analysis - 3

Parameter	Analytes	Reason for Testing	Method of Analysis
Organic Scan (soil)	Various chlorinated aliphatic hydrocarbons	Indicator of presence of halogenated hydrocarbons	Suitable pretreatment, extraction with methylene chloride followed by GC (3% SP-2250 on 100/120 Supelcoport).
Chloro-benzene (soil)	Various chlorobenzenes	Indicator of presence of chlorinated solvents101)	Extraction followed by GC (packed OV
PAH (soil)	Benz-a-pyrene and others	Indicator of wide variety of PAHs possibly present in tank bottoms, etc. Suspected carcinogen.	Extract with methylene chloride, followed by HPLC (reverse phase, C 18) and fluorescence detection or Extract with hexane followed by GC (Vocol wide-bore capillary column-Supelco).
Amines (soil)	Ethanol Amines	Associated with oil refining	Extract with basic water (1 N NaOH) followed by GC (Tenax GC 60/80 3' x 2 mm ID glass column).

APPENDIX F

SOIL CHEMISTRY

APPENDIX F.1

COME BY CHANCE PROJECT
SOIL SAMPLES (FULL ANALYSIS)

Lab Id.	Site	Location	O & G ug/g	Phenolics ug/g	Zn ug/g	Pb ug/g	Cu ug/g	Ni ug/g	Cr ug/g	V ug/g	As ug/g	Cd ug/g	PCB ug/g	m-ea* ug/g	d-ea* ug/g	t-ea* ug/g
C0215	TF	tp2-1	493	0.15	47.8	31.6	13.8	87.6	6.4	<18	.40	<.3	<0.02	<1	<1	ND
C0232	TF	bh1-4	28	0.099	17.9	10.1	14.0	2.9	2.9	<18	.76	<.3				
C0234	TF	bh2-1	674	0.17	14.9	7.7	11.8	13.1	4.0	<18	.90	<.3				
C0235	TF	bh2-2	198	0.13	14.2	3.9	12.1	6.8	3.7	<18	.73	<.3				
C0236	TF	bh2-3	138	0.085	15.2	3.7	10.1	4.1	2.7	<18	.92	<.3				
C0237	TF	bh2-4	83	0.13	12.7	3.8	12.1	3.4	2.8	<18	.46	<.3				
C0239	TF	bh3-2	62	0.11	9.6	6.2	9.8	6.8	16.9	29.4	.13	.30				
C0244	TF	bh3-5	39	0.16	8.0	3.6	9.1	1.9	2.4	<18	.48	.65				
C0246	TF	bh4-2	6814	0.14	10.6	6.1	6.9	7.5	2.0	<18	1.01	<.3				
Surface sample	TF	(near TP2)	19688	0.14	3.8	5.7	1.8	3.2	5.6	241	.69	<.3				
bkgrnd1	TF	(s of rd)	60	0.54	6.4	4.5	6.3	1.7	1.0	2.3	.34	<.03				
bkgrnd2	TF	(new wd)	92	0.31	5.0	7.6	7.2	1.8	1.1	4.0	.41	<.03				
C0165	MB	a4-1	24305	0.39	30.3	20.7	6.7	477	4.8	<18	.27	<.3	<0.1	<1	<1	ND
C0167	MB	a4-2	12498	0.24	15.1	32.5	4.9	5.2	3.6	<18	.77	.50				
C0169	MB	a5-1	38641	1.50	67.7	101.7	12.4	7.4	11.4	100.6	.45	.51				
C0170	MB	a5-2	1181	0.12	30.3	76.9	8.5	9.9	8.3	<18	.20	<.3				
C0171	MB	a6-1	120	0.076	29.5	41.2	15.6	2.8	6.6	20.3	.54	.30				
C0172	MB	a6-2	10	<.05	17.2	38.4	15.5	4.0	3.9	<18	.83	<.3				
C0219	MB	tp2-2	15574	0.44	68.7	29.7	15.0	4.0	3.4	<18	1.56	.27				
C0222	MB	tp3-1	6046	0.15	21.7	7.6	14.1	58.4	34.2	<18	.36	.43				
C0223	MB	tp3-2	169	0.07	15.5	7.8	9.8	8.1	4.1	<18	.44	<.3				
C0225	MB	tp4-1	25	0.075	14.1	10.7	14.0	4.0	1.4	<18	.87	<.3				
C0195	MB	bh3-2 (bkgrnd)	ND	0.25	5.66	3.3	9.3	3.1	1.1	<18	1.84	<.3				
C0201	MB	bh4-2	44	0.125	13.8	5.2	37.1	5.5	2.5	<18	.36	<.3				
OMOE "Cleanup Criteria"			20000		800	1000	300	200	1000	250	50	8				
Netherlands "Reference Background"				0.02									0.05			
Netherlands "Further Investigation"				1									1			
Netherlands "Cleanup Criteria"				10									10			

* mono-ethanol amines
di-ethanol amines
tri-ethanol amines
ND not detected

Appendix F.1
Come by Chance Project
Soil samples (full analysis) - 2

Lab Id.	Site	Location	O & G ug/g	Phenolics ug/g	Zn ug/g	Pb ug/g	Cu ug/g	Ni ug/g	Cr ug/g	V ug/g	As ug/g	Cd ug/g	PCB ug/g	m-ea* ug/g	d-ea* ug/g	t-ea* ug/g
C0180	WD	tp4-1	197	0.077	27.5	39.7	62.7	3.1	3.3	<18	1.62	<.3				
C0228	WD	tp5-3	5426	0.30	36.1	8.3	9.3	3.8	3.3	<18	.39	<.3				
C0249	WD	bh1-2	89	0.12	15.9	6.5	16.5	4.9	3.4	<18	.75	<.3				
C0253	WD	bh2-3	338	0.51	27.1	13.9	14.3	3.2	3.7	<18	.94	<.3				
C0254	WD	bh2-4	446	<.05	16.5	4.0	15.3	3.1	3.2	<18	.41	.30				
C0255	WD	bh3-1	431	0.94	139.8	18.3	18.8	13.7	7.3	<18	.52	<.3				
C0258	WD	bh3-4	ND	<.05	9.4	5.6	17.7	2.4	2.7	<18	1.48	<.3				
C0259	WD	bh4-1	5480	0.29	9.2	11.1	4.2	2.8	6.2	18.4	.95	<.3		<1	<1	ND
C0260	WD	bh4-2	316	0.072	19.9	4.3	12.8	3.9	3.2	<18	.51	<.3				
C0264	WD	bh5-4	604	0.31	7.4	4.5	11.3	1.3	2.7	<18	.41	<.3				
C0266	WD	bh6-2	339	0.091	13.3	7.0	13.4	2.0	3.1	<18	1.39	.30				
C0267	WD	bh6-3	60	0.12	14.7	7.4	15.2	0.7	3.6	<18	1.39	<.3				
C0268	WD	bh6-4	69	0.099	13.1	7.5	15.4	3.2	3.6	<18	.63	.31				
C0270	WD	bh7-2	234	0.21	23.9	8.4	13.1	3.0	2.4	<18	.59	<.3				
C0271	WD	bh7-3	ND	0.064	10.6	4.9	6.2	2.3	2.3	<18	.27	<.3				
C0272	WD	bh7-4	ND	0.12	13.8	5.9	8.8	3.2	4.0	<18	.25	<.3				
1	WD	ls1	1038	0.15	1540	9.2	57.6	290	4.1	<18	<.05	7.8				
2	WD	ls2	652	<.05	33.5	6.2	17.0	5.1	4.5	<18	.18	<.3				
3	WD	ls3	870	0.10	31.5	7.1	30.0	62.3	61.9	<18	1.09	.5				
4	WD	ls4	183	0.09	19.6	1.5	15.2	4.0	8.4	<18	.17	<.3				
5	WD	ls5	ND	<.05	15.0	3.0	18.0	4.8	5.0	<18	.19	<.3				
6	WD	ls6	57	0.026	13.9	4.3	5.0	3.5	3.0	2.2	.46	<.03				
dup6	WD	ls6			13.3	6.0	5.8	4.2	3.1	2.7	.66	<.03				
Surface sample	WD	(bkgrnd)	39	<.05	.74	0.6	1.7	<1	.9	<18	.51	<.3				
OMOE "Cleanup Criteria"			20000		800	1000	300	200	1000	250	50	8				
Netherlands "Reference Background"				0.02									0.05			
Netherlands "Further Investigation"				1									1			
Netherlands "Cleanup Criteria"				10									10			

* mono-ethanol amines
di-ethanol amines
tri-ethanol amines
ND not detected

APPENDIX F.2

COMZ BY CHANCE PROJECT
SOIL SAMPLES (NO METALS ANALYSIS)

Lab Id.	Site	Location	Oil & Grease	PCB	m-ethanol amine	d-ethanol amine	t-ethanol amine
			ug/g	ug/g	ug/g	ug/g	ug/g
C0213	TF	tp1-1	569		<1	<1	ND
C0214	TF	tp1-2	118				
C0216	TF	tp3-1	20				
C0217	TF	tp3-2	30				
C0155	MB	a1-1	22423				
C0156	MB	a1-2	28668		<1	<1	ND
C0157	MB	a2-1	1339				
C0159	MB	a2-2	5316				
C0161	MB	a3-1	8585				
C0163	MB	a3-2	3181				
C0173	MB	a7-1	1438				
C0174	MB	a7-2	363				
C0175	MB	a8-1	1391				
C0176	MB	a8-2	ND				
C0177	MB	a9-1	ND				
C0218	MB	tp2-1	8617				
C0220	MB	tp2-3	1243				
C0221	MB	tp2-4	175				
C0224	MB	tp3-3	ND				
C0226	MB	tp4-2	95				
C0225	MB	tp4-1	ND				
C0178	WD	tp1-1	206				
C0179	WD	tp1-2	247				
C0181	WD	tp5-1	1828				
C0182	WD	tp5-2	2462	<0.02	<1	<1	ND
C0183	WD	tp6-1	ND				
C0184	WD	tp6-2	5				
OMOE "Cleanup Criteria"			20000				
Netherlands "Reference Background"				0.05			
Netherlands "Further Investigation"				1			
Netherlands "Cleanup Criteria"				10			

ND not detected

APPENDIX F.3

COME BY CHANCE PROJECT
SOIL SAMPLES (CHLOROBENZENES)

	C0219 TF bh2-1 ug/g	C0246 MB a5-1 ug/g	C0259 WD tp5-3 ug/g
p-dichlorobenzene	<0.02	<0.02	<0.02
o-dichlorobenzene	<0.02	<0.02	<0.02
m-dichlorobenzene	<0.02	<0.02	<0.02
1,2,3-trichlorobenzene	<0.002	<0.002	<0.002
1,2,4-trichlorobenzene	<0.002	<0.002	<0.002
1,3,5-trichlorobenzene	<0.002	<0.002	<0.002
1,2,3,4-tetrachlorobenzene	<0.002	<0.002	<0.002
1,2,3,5-tetrachlorobenzene	<0.002	<0.002	<0.002
1,2,4,5-tetrachlorobenzene	<0.002	<0.002	<0.002
pentachlorobenzene	<0.002	<0.002	<0.002
hexachlorobenzene	<0.002	<0.002	<0.002

APPENDIX F.4

COME BY CHANCE PROJECT
SOIL SAMPLES (POLYCYCLIC AROMATIC HYDROCARBONS)

	C0246 TF bh4-2 ug/g	C0169 MB a5-1 ug/g	C0219 MB tp2-2 ug/g	C0259 WD bh4-1 ug/g
Napthalene	<0.04	<0.1	<0.4	<0.04
Acenaphthylene	<0.2	<0.1	<1.0	<0.2
Acenaphthene	<0.04	1.9	<0.4	<0.04
Fluorene	<0.02	0.6	<0.2	<0.02
Phenanthrene	<0.03	(1.0	<0.03	<0.03
Anthracene	<0.2	(	<2.0	<0.2
Fluoranthene	<0.009	2.3	<0.09	<0.009
Pyrene	<0.03	1.5	0.18	<0.03
Triphenylene	<0.03		<0.3	<0.03
Benz (a) anthracene	<0.007	<2	0.13	<0.007
Chrysene	<0.02	<2	<0.2	<0.02
Benzo (e) pyrene	<0.02		<0.2	<0.02
Benzo (b) fluoranthene	<0.003	(<2	<0.03	<0.003
Benzo (k) fluoranthene	<0.001	(	<0.01	<0.001
Benzo (a) pyrene	<0.004	<3.5	<0.04	<0.004
Indeno (1,2,3-c,d)pyrene		(<3.5		
Dibenzo (a,h) anthracene		(		
Benzo (g,h,i) perylene		<3.5		

APPENDIX F.5

COME BY CHANCE PROJECT
SOIL SAMPLES (HALOGENATED ALIPHATIC COMPOUNDS)

	MB A4-1 6165 (ppm)	TFTP1-1 6213 (ppm)	WDBH5-4 6264 (ppm)	TFBH4-2 6246 (ppm)	WDTP5-2 6182 (ppm)	MBA5-1 6169 (ppm)
Tetrachloroethylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Trichloroethylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
trans-1,2-Dichloroethylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,1-Dichloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,1,1-Trichloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-Dichloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carbon Tetrachloride	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,3-Dichloropropylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
cis-1,2-Dichloroethylene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
2-Chloroethyl Vinyl Ether	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
2,3-Dichloro-1-propene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Vinyl Chloride	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,1,2-Trichloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-Dichloropropane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,2-Dibromomethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Methyl Chloride	<0.05	<0.05	<0.05	<0.05	<0 05	<0.05
Bromochloromethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
1,1,2,2-Tetrachloroethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Methylene Chloride	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluorotrichloromethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloroform	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bromodichloromethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Dibromochloromethane	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bromoform	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

APPENDIX G

WATER CHEMISTRY

APPENDIX G.1

COME BY CHANCE PROJECT

GROUNDWATER AND SURFACE WATER SAMPLES

Site	Sample Location	O & G mg/L	Phenol mg/L	Zn mg/L	Pb mg/L	Cu mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	V mg/L	Cr mg/L	Ni mg/L	As mg/L	Cd mg/L	pH	Cond uS/cm	Cl mg/L	NO3-N mg/L	SO4 mg/L	Alk mg CaCO3/L
TF	bh 1	1.8	.009	.120	<.2	<.02	128.5	54.8	62.0	3.57	<2	<.08	<.1	<.005	<.03	7.95	1295	39.4	.013	321.8	370
TF	bh 2	3.8	.012	.140	<.2	<.02	127.4	29.0	41.5	5.96	<2	<.08	<.1	<.005	<.03	7.24	980	52.1	<.01	146.4	270
TF	bh 3	2.8	.024	.405	<.2	<.02	32.6	10.9	26.4	1.45	<2	<.08	<.1	<.005	<.03	7.19	377	18.9	.077	845.67	166
TF	bh 4	5.7	.038	.040	<.2	<.02	3.1	1.6	13.5	1.81	<2	<.08	<.1	<.005	<.03	5.73	110	28.1	.021	.91	6.3
MB	bh 1	3.5	.002	.090	<.2	<.02	82.9	33.0	2.23	2.40	<2	<.08	<.1	<.005	<.03	7.92	672	11.7	<.01	151.5	205
MB	bh 2	5.6	.019	.110	<.2	<.02	27.9	3.9	9.95	1.79	<2	<.08	<.1	<.005	<.03	7.44	219	17.6	.122	1.52	86.1
MB	bh 3	2.8	.002	.018	<.2	<.02	46.2	4.6	10.1	2.34	<2	<.08	<.1	<.005	<.03	7.88	334	12.2	.016	15.6	136
MB	bh 4	27.7	.070	.070	<.2	<.02	105.2	11.4	90.9	54.9	<2	<.08	<.1	<.005	<.03	7.43	1074	30.6	<.01	132.0	425
MB	bh 4*	17.3	.030																		
MB	pond	.63	.003	<.02	<.2	<.02	31.0	8.2	20.5	2.26	<2	<.08	<.1	<.005	<.03	7.90	327	34.7	<.01	59.5	47.7
WD	bh 1	3.7	.006																		
WD	bh 2	9.5	.005	.590	<.2	<.02	58.0	8.5	25.8	3.8	<2	<.08	<.1	<.005	<.03	7.12	426	35 9	.26	13.9	144
WD	bh 3	28.5																			
WD	bh 4	6.1	.015	.038	<.2	<.02	83.5	35.0	48.5	3.94	<2	<.08	<.1	<.005	<.03	7.95	1101	102.9	<.01	65.2	341
WD	bh 5	12																			
WD	bh 6	3.6	< 001	<.02	<.2	<.02	215.4	78.0	40.9	4.0	<2	<.08	<.1	<.005	<.03	7.38	1420	54.7	.26	7.1	730
WD	bh 7	1.1	.005	.042	<.2	<.02	17.1	5.15	9.98	1.71	<2	<.08	<.1	<.005	<.03	7.70	222	15.7	<.01	5.96	78.2
WD	ls 5			21.6	<.2	5.4					.008	1.2	6.4	<.005	0.06						
WD	ls 6			5.9	<.2	0.2					<.005	<.1	1.5	<.005	<.03						
WD	trench	3.3	.006	.040	<.2	0.04	99.1	11.4	14.4	4.08	<2	<.08	1.47	<.005	<.03	8.30	630	8.83	<.01	175.6	151
WD	Bog(bh 7)	.7	.006	<.02	<.2	<.02	60.4	12.3	25.8	3.73	<2	<.08	<.1	<.005	<.03	7.61	459	21.3	<.01	2.2	205.4
WD	Quarry	.1	.004	<.02	<.2	<.02	24.5	18.8	19.9	2.63	<2	<.08	<.1	<.005	<.03	8.32	328	10.1	.035	9.2	149
	Water Supply	1.0	.002	<.02	<.2	<.09					<.005	<.1	<.08	<.005	<.03						
Drinking Water Standards			.002	5.0	.05	1.0						.05		.05	.005	6.5-8.5		250	10	500	

*Duplicate

APPENDIX G.2

COME BY CHANCE PROJECT

GROUNDWATER AND SURFACE WATER SAMPLES

Site	Sample Location	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	alkalinity mg/L CaCO3	sulfate mg/L	chloride mg/L
TF	bh1	128.5	54.8	62.0	3.57	370	321.8	38.4
TF	bh2	127.4	29.0	41.5	5.86	270	148.4	52.1
TF	bh3	32.6	10.9	26.4	1.45	166	8.7	18.9
TF	bh4	3.1	1.6	13.5	1.61	6	0.9	28.1
MB	bh1	82.9	33.0	2.23	2.40	205	151.5	11.7
MB	bh2	27.9	3.9	9.95	1.79	86	1.5	17.6
MB	bh3	46.2	4.6	10.1	2.34	136	15.6	12.2
MB	bh4	105.2	11.4	90.9	54.88	425	132.0	30.6
MB	pond	31.0	8.2	20.5	2.28	48	59.5	34.7
WD	bh2	58.0	8.5	25.8	3.80	144	13.9	35.9
WD	bh4	83.5	35.0	48.3	3.94	341	65.2	102.9
WD	bh6	215.4	78.0	40.9	4.00	730	7.1	54.7
WD	bh7	17.1	5.2	9.90	1.71	78	6.0	15.7
WD	trench	99.1	11.4	14.4	4.08	151	175.6	8.8
WD	bog (bh7)	60.4	12.3	25.8	3.73	205	2.2	21.3
WD	quarry	24.5	18.8	19.9	2.63	149	9.2	10.1

Ca meq/L	Mg meq/L	Na meq/L	K meq/L	cations meq/L	bicarbonate meq/L	SO4 meq/L	Cl meq/L	anions meq/L	Percent Error
6.43	4.49	2.70	0.09	13.70	7.40	6.70	1.11	15.21	5.2
6.37	2.38	1.80	0.15	10.70	5.40	3.05	1.47	9.92	-3.8
1.63	0.89	1.15	0.04	3.71	3.32	0.18	0.53	4.03	4.2
0.16	0.13	0.50	0.05	0.92	0.13	0.02	0.79	0.94	0.9
4.15	2.70	0.10	0.06	7.01	4.10	3.16	0.33	7.59	4.0
1.40	0.32	0.43	0.05	2.19	1.72	0.03	0.50	2.25	1.3
2.31	0.38	0.44	0.06	3.19	2.72	0.33	0.34	3.39	3.1
5.26	0.03	3.95	1.40	11.55	8.50	2.75	0.86	12.11	2.4
1.55	0.67	0.88	0.06	3.17	0.95	1.24	0.98	3.17	0.0
2.90	0.70	1.12	0.10	4.82	2.88	0.29	1.01	4.18	-7.1
4.18	2.87	2.10	0.10	9.24	6.82	1.36	2.90	11.08	9.0
10.77	6.39	1.78	0.10	19.04	14.60	0.15	1.54	16.29	-7.8
0.88	0.42	0.43	0.04	1.75	1.56	0.12	0.44	2.13	9.7
4.96	0.93	0.63	0.10	6.62	3.02	3.66	0.25	6.93	2.3
3.02	1.01	1.12	0.10	5.25	4.11	0.05	0.60	4.75	-4.9
1.23	1.54	0.87	0.07	3.70	2.98	0.19	0.28	3.46	-3.4